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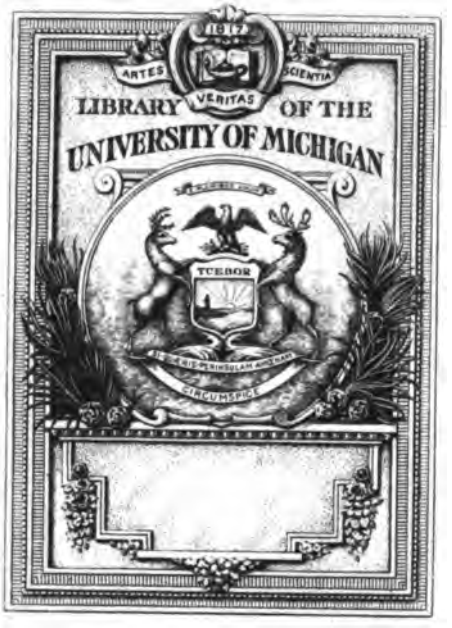

THE GIFT OF
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MINISTRY OF FINANCE

SURVEY DEPARTMENT,

EGYPT.

THE RAINS OF THE NILE BASIN

IN 1904

BY

CAPTAIN H. G. LYONS,

DIRECTOR GENERAL, SURVEY DEPARTMENT.

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THE RAINS OF THE NILE BASIN IN 1904.

From April to September each year the rainfall of the Nile basin should be of great interest to all who live in Egypt and the Sudan. In early April or even the second half of March the first rain storms break on the southern end of the Abyssinian tableland and add a small and almost inappreciable contribution to the low stage supply of the Nile, which has by this time fallen almost to its lowest in Egypt and every available drop is required for irrigation. After this, as the months of summer arrive, reports are received weekly, fortnightly, or even monthly from the more remote portions of the basin, and the amount of rain which has fallen at various points is published for information. But this is of little practical value so long as the average rainfall and its distribution is not generally known, and at the present time such work as has from time to time been done on this subject is not readily accessible in this country. I have endeavoured therefore to collect in a convenient form such data as may give an approximate idea of the average rainfall and to compare with them the results of such observations as were made in 1904, in order to illustrate the seasonal increase and decrease of precipitation over this area.

Five years ago there were not more than six or eight places in the Nile basin where the rainfall was being measured regularly, while to-day there are more than forty, of which thirty-two lie to the south of Berber (lat. 18° N.). The parts played by the different tributaries of the Nile have also been determined during the last few years * so that we are now able to recognize with very fair accuracy the share which the rainfall of the different districts takes in supplying the Nile, and to trace the effects of excessive or deficient rainfall in any area. The next step towards a thorough understanding of the conditions which govern the rainfall is to trace the relation between the rainfall in different parts of the basin, but this is not so simple. We are as yet far from knowing why the north of the Uganda province had phenomenally heavy rains in 1903 while the Nile flood supplied by the rains of the Abyssinian tableland was 11 per cent below the average, or why

* "A Report on the Basin of the Upper Nile." Sir W. Garstin, G.C.M.G., Cairo, 1904.

the rains of 1902 and 1904 were heavy and fairly heavy in the southern area while the Abyssinian rains were very much below the average, the Nile flood being only 0·63 and 0·75 of the volume of an average flood. * It is therefore with the view of advancing our knowledge of the conditions which affect the rainfall in these regions that the present discussion is undertaken. The materials utilized are derived from various sources; the stations in Egypt and the Sudan forward their observations to the Survey Department for compilation and publication, while Dr. Wakeman, of the British Agency at Addis Abbaba, sends observations from there. For Erithrœa they are published monthly in the "Bollettino Agricolo e commerciale della Colonia Eritrea." †

From Uganda and British East Africa the very valuable rainfall data are communicated monthly by the Directors of the Scientific Departments by the permission of the Colonial Office.

In order to understand properly the seasonal variation of the rainfall, the relative positions of the equatorial low pressure belt and the high pressure areas to the north and south of it at different seasons must be borne in mind. In this central low pressure area there is an ascensional movement of the air, so that its moisture is condensed to form clouds and rain. As the air flows upwards and outwards, its place is taken by air which flows in from the high pressure areas to the north and south, as north-easterly and south-easterly trade winds. This ascensional movement is most marked where the heating effect of the sun is greatest, and this will be where the sun is in the zenith at noon.

In January the thermal equator is far south of the geographical one and the sun is in the zenith at noon between 22°. 58′ S. and 17°. 14′ S., while the line of low pressure lies rather further to the north. ‡ The heaviest rainfall is now in the neighbourhood of lake Nyassa, and lighter rain falls as far as lake Victoria, while it may become heavy whenever the south-east trade winds strike high hills, and the air is forced to rise. Over all Egypt and the Sudan this month is rainless, except in the northern Delta where the cyclonic storms of the Mediterranean furnish a moderate rainfall, and along the west shore of the Red Sea where there are also winter rains, but these last are not within the Nile basin.

In February the sun is overhead at noon between lat. 16°. 57′ S. and 7°. 46′ S., while the low pressure belt has moved northwards; the

* Considering the flood as represented by the volume of water passing Aswan between July 1 and October 31.

† Published at Asmara.

‡ Compare Herbertson. "The distribution of rainfall over the land." Royal Geog. Soc. London, 1901.

heaviest rainfall is in the neighbourhood of the north of lake Nyassa and the south of lake Tanganika.

In March the noonday sun is vertical between 7°. 23′ S. and 4°. 21′ N. and heavy rainfall occurs west of lake Victoria while there is a marked increase all over the lake basin and in northern Uganda, while the first showers fall in southern Abyssinia.

In April the sun is between lat. 4°. 44′ N. and lat. 10°. 56′ N., while the low pressure area lies over the southern Sudan. Rainfall is heavy over the lake plateau, while the first rains begin on the Bahr el Jebel, the Sobat and southern Abyssinia.

In May the zenithal midday sun lies between lat. 15°. 14′ N. and lat. 22°. 0′ N.; the low pressure has moved further north, and rainfall is heavy on the lake plateau, the southern Sudan, and southern Abyssinia, while it is beginning in northern Abyssinia.

In June the sun reaches its greatest declination north, and begins to return southwards; the low pressure area includes all the Sudan plains where the rain is heavy, while on the lake plateau it has materially diminished. On the Abyssinian tableland it is increasing rapidly being already very heavy in Kaffa and Wallega south of the Abai river.

In July the sun is in the zenith at noon at 23°. 5′ N. in the beginning and at 18°. 10′ N. at the end of the month. Low pressure lies over the Sudan and the minimum is situated near Suakin-Berber-Khartoum; rainfall has diminished greatly on the lake plateau where the dry season with its rapid evaporation has set in; on the Bahr el Jebel the rains have moderated somewhat, but on the Abyssinian tableland and in the northern Sudan they are heavy.

August is very like July though the sun's north declination has considerably decreased and by the end of the month it is in the zenith at noon in lat. 8°. 29′ N. The equatorial rain-belt has also moved southwards, but over the whole Sudan and the Abyssinian tableland the rains are normally at their maximum.

In September the conditions change rapidly as the sun is zenithal at noon between 8°. 7′ N. and 3° S.; pressure rises rapidly over the Sudan and Abyssinia and the rains decrease, so that by the middle of the month the rainy season is considered to be at an end, except on the southern part of the Abyssinian tableland, on the upper reaches of the Bahr el Jebel, and the northern extension of the lake plateau where it is still heavy. Near the lakes the rainfall increases again as the rain belt returns southward.

By October dry hot weather has set in over most of the Sudan though rain still falls on the Bahr el Jebel and heavily in its southern

part. The sun has passed the equator and is zenithal between 3°. 23′ S. and 14°. 17′ S. Rain increases over all the lake plateau and is heaviest on the hills of northern Uganda and round the Albert lake.

By November when the sun is in the zenith at noon between 14°. 36′ S. and 21°. 45′ S. rainfall is heaviest over the whole lake plateau forming the autumn rainy season of this part; from the high altitude of much of the country in the north of Uganda as far as lat. 3°. N. rain is still falling heavily there though it has practically ceased in the southern plateau of Abyssinia, while on the Sudan plains no rain now falls.

In December the conditions are almost the same as those of January, except that the rainfall on the lake plateau is heavier; the sun is at its extreme southern limit and the whole of the basin north of lat. 1° N. is practically rainless. The heaviest rainfall has moved south to the Tanganika-Nyassa area and Tabora, 150 kilometres south of lake Victoria, is now receiving its heaviest rain. On the western shores of the Red Sea the winter rains have recommenced, and also on the Mediterranean shores of the Delta.

Having now described shortly the periodical oscillation of the rainfall from south to north, and back to south again, we can more easily follow the variations of the rainfall of 1904. For most of this the calendar year is a convenient division since the maximum rainfall is in the summer, but for the study of the winter rains it is not so convenient since their season is from November to February.

They had better therefore be taken separately, and this may be done the more easily as they do not affect the Nile supply, but are purely local in their effects. Those of the Red Sea hills lie outside the Nile basin, while the Mediterranean coast rains are mainly of importance for the crops of barley, etc., which are raised on the coast belt to the west of Alexandria.

The total rainfall at Cairo in 1904 was 24 millimetres as compared with the mean amount 31 mm., but this rainfall as well as the occasional showers recorded in Upper Egypt are unimportant. At Helwan Observatory the amount was 50 mm.

Table I.—Delta Winter Rains 1903-1904 in Millimetres.*

Month	Alexandria.	Mex.	Kafr Dawar.	Abu Homos.	Atf.	Damanhur.	Shubrakhit.	Teh el Barud.	Kafr Bulin.	Khatatba.	Hosh Issa.
October 1903	0·0	Observations commenced November 1903.									
November „	9·9	3·3	1·0	1·8	0·5	1·7	0·0	0·0	0·0	0·0	0·0
December „	23·8	21·5	3·5	3·8	1·5	3·5	4·8	5·1	8·0	3·0	2·0
January 1904	62·7	53·7	42·0	12·8	23·1	14·4	15·0	11·0	15·8	14·8	24·0
February „	12·5	14·9	19·5	34·2	33·8	19·0	16·8	13·5	14·5	8·2	12·2
March „	0·4	1·3	4·5	4·6	4·0	3·8	2·8	2·8	6·2	1·5	0·0
Total Nov.-March.	109·3	94·7	70·5	57·2	62·9	42·4	39·4	32·4	44·5	27·5	38·2

Delta Winter Rains 1904-1905 in Millimetres.

Month	Alexandria.	Mex.	Kafr Dawar.	Abu Homos.	Atf.	Damanhur.	Shubrakhit.	Teh el Barud.	Kafr Bulin.	Khatatba.	Hosh Issa.
October 1904	2·7	24·6	45·0	7·2	0·8	3·5	2·2	0·0	0·0	1·0	0·0
November „	64·9	70·9	42·8	29·0	39·0	19·5	12·8	10·5	17·5	1·8	21·6
December „	50·5	61·4	67·5	45·4	52·0	35·8	57·0	29·6	35·5	8·8	45·7
January 1905	45·8	46·7	27·6	10·6	21·8	0·5	10·0	8·1	5·0	0·8	5·5
February „	15·9	27·7	55·5	22·5	33·0	17·8	14·2	16·2	11·5	2·2	20·0
March „	14·1	14·7	7·5	10·5	29·5	24·5	16·5	15·5	11·0	7·0	18·5
Total Oct.-March.	193·9	246·0	245·9	125·2	176·1	101·6	112·7	79·9	80·5	21·6	111·3

On the western shore of the Red Sea the winter rains are of importance though they do not reach the Nile basin. In years of heavy rainfall in Abyssinia a little rain may fall at Suakin in July but usually the rainy season there is from October to February. At Massaua it is the same and as the tableland is approached the rains encroach on the summer months till at Ghinda both rainy seasons are experienced.

Mean Rainfall in Millimetres

	Years of Observation	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Year.
Suakin.	14	28	11	0	1	1	0	4	6	0	38	93	59	241

* All these stations are in Beheira province on the west of the Delta.

RAINFALL 1904 IN MILLIMETRES

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Year.
Suakin ...	8	0	0	0	0	0	0	0	0	87	60	19	174

In Table II is given the total rainfall for each month for thirty stations from Khartoum on the north to Mbarara, west of lake Victoria, on the south. There are besides the German stations of Bukoba, Muanza, and Shirati on the shore of lake Victoria, and probably the mission station of Masaba close to Mount Elgon since observations were taken there in 1903, but it has not been possible to obtain the results of these observations for 1904 in time for insertion.

For comparison with these totals the mean monthly rainfall is given in Table III, but for these mean values but little accuracy can be claimed as only five stations have observations which extend over more than five years. The most that can be said is that the table furnishes the best approximations to the mean values which it is possible to obtain at present.

The difference between the stations on the north with a single rainy season and the equatorial stations where there are two rainy seasons and two dry seasons is well shown in both tables, and the line of demarcation seems to be somewhat north of Wadelai; signs of it occur in the Nimule and Gondokoro observations, but these series are not sufficiently long to give reliable results. It is characteristic of the rainfall in these parts that it falls in heavy downpours and usually as a violent thunderstorm ; places at a comparatively short distance apart may in any year receive very different amounts of rain, so that a comparatively long series of observations is necessary before a good value of the average rainfall and its distribution in the Nile basin can be obtained.

As the mean values are not yet reliable, the difference between the rainfall of 1904 and that of 1903 is given in Table IV. But these data must be used with caution for while in 1903 the Abyssinian rainfall supplied a flood which at first was weak, but improved in August and September until the total volume was only about 11 per cent below a mean flood, in northern Uganda and the upper reaches of the Bahr el Jebel the rainfall was phenomenally heavy, high river banks were flooded, and huts of the natives were submerged which had for some years past been considered as above flood level.

Table II.—MONTHLY RAINFALL 1904 IN MILLIMETRES

Place.	Jan.	Feb.	March.	April.	May.	June.	July.	August.	Sept.	Oct.	Nov.	Dec.	Year.
Sudan Plains.													
Khartoum	0	0	0	0	0	0	34	**76**	20	0	0	0	130
Kassala	0	0	0	0	4	6	58	62	**127**	59	4	0	320
Khashm el Girba...	...	...	...	...	...	0	58	**95**	54	37	0	0	244
El Obeid	0	0	17	0	2	18	**149**	67	53	6	0	0	312
El Dueim	0	0	0	0	0	9	**53**	46	**53**	0	2	0	163
Wad Medani... ...	0	0	0	0	40	0	**85**	67	77	4	12	0	285
Gedaref...	0	0	5	0	33	29	146	**216**	97	29	2	0	587
Gallabat...	0	0	0	2	65	131	**266**	169	210	37	11	0	891
Roseires...	...	...	...	0	37	52	**290**	222	104	1	0	0	706
Kodok	0	0	9	9	56	**147**	78	76	81	38	0	0	494
Sobat.													
Doleib Hilla... ...	0	0	47	62	101	132	**186**	153	78	30	9	0	798
Nasser	1	0	27	7	118	152	210	**236**	74	24	21	0	880
Abyssinian Tableland.													
Asmara	...	...	...	28	9	36	32	**136**	110	10	56	0	[417]
Addi Ugri	...	...	...	...	...	100	**138**	111	13	...	...	...	[362]
Chenafena	...	...	...	5	13	47	**149**	90	3	...	...	...	[307]
Addis Abbaba ...	0	49	171	56	66	120	**375**	192	198	44	...	...	[1271]
Bahr el Ghazal.													
Wau.	< ...	36	...>	19	134	**169**	107	120	77	44	10	0	716
Bahr el Jebel.													
Ghaba Shambe ...	0	2	1	24	102	22	53	**112**	88	46	3	0	453
Mongalla..	0	21	110	83	130	112	49	154	71	**160**	11	11	912
Gondokoro	1	32	105	79	**193**	57	102	190	103	119	32	6	1019
Nimule	0	0	141	48	24	67	**164**	98	134	123	127	38	964
Wadelai...	10	36	118	**145**	118	59	122	144	60	138	**199**	18	1167
Lake Albert.													
Butiaba...	29	6	131	**137**	99	123	29	58	37	**130**	96	90	965
Fort Portal	55	67	**209**	90	115	26	21	122	164	**275**	69	84	1297
Lake Victoria.													
Entebbe...	42	91	**250**	172	242	137	46	106	59	66	**203**	186	1600
Jinja.	48	47	145	**151**	77	62	22	125	73	88	**147**	131	1116
Mumias...	18	66	152	**279**	172	221	175	203	**126**	**126**	96	114	1748
Kisumu...	0	36	96	122	**146**	17	43	118	43	91	144	**249**	1105
Masaka...	71	127	84	226	**242**	14	4	43	113	92	121	**139**	1276
Mbarara...	159	162	**188**	126	181	0	43	256	291	311	**345**	254	2316

Table III.—MEAN MONTHLY RAINFALL IN MILLIMETRES.

	Years.	Jan.	Feb.	March.	April.	May.	June.	July.	August.	Sept.	Oct.	Nov.	Dec.	Year
Sudan Plains.														
Khartoum	6	0	0	0	0	4	26	26	**27**	11	4	**0**	0	9
Kassala	5	0	0	0	2	8	23	62	**104**	26	21	**1**	0	247
Khashm el Girba.	2	...	...	...	...	...	15	66	**117**	61	18	**0**	0	[27
El Obeid	1¹⁄₁₂	0	0	17	0	2	18	89	**115**	37	4	**0**	0	28
El Dueim	3	0	0	0	0	17	3	**91**	58	44	3	**1**	0	217
Wad Medani ...	3	0	0	0	0	16	32	**115**	79	68	2	**4**	0	316
Gedaref	1¹⁄₁₂	0	0	5	0	33	59	128	**210**	109	14	**1**	0	55
Gallabat	1¹⁄₁₂	0	0	0	2	65	131	220	**234**	172	20	**6**	0	85
Roseires	1¹⁄₁₂	...	...	...	0	37	52	**246**	203	155	8	**5**	0	[70
Kodok...	4¹⁄₁₂	0	1	2	15	83	133	108	**240**	95	53	**0**	0	79
Sobat.														
Doleib Hilla ...	1¹⁄₁₂	0	0	47	62	84	141	**178**	158	128	101	**25**	0	92
Nasser...	1¹⁄₁₂	1	0	27	7	118	152	210	**236**	74	34	**21**	0	877
Abyssinian Tableland.														
Ghinda	4	78	127	**160**	17	16	7	58	61	30	32	**77**	**112**	77
Keren...	5¼	0	3	2	9	25	107	106	***300**	78	2	**8**	0	74
Asmara	1	...	...	28	9	36	32	**136**	110	10	56	...	...	[41
Chenafena	2	...	...	...	3	54	33	130	**150**	19	8	0	0	39
Halai	1	...	...	...	...	63	15	114	**154**	4	2	6	0	[35
Addi Ugri	7¼	0	6	16	23	43	67	148	**178**	34	6	8	6	53
Adua	1	...	...	...	...	...	51	236	**289**	209	65	...	...	[85
Intetshau	1	...	...	...	37	68	74	**302**	177	126	0	0	0	[78
Gondar	3	0	0	0	0	67	122	290	**372**	103	46	14	0	129
Addis Abbaba ...	5¼	10	45	107	79	89	158	**298**	270	180	17	7	6	126
Bahr el Ghazal.														
Wau	1	< ...		36 ...>	19	134	**169**	107	120	77	44	10	0	716
Bahr el Jebel.														
Ghaba Shambe ...	1	0	2	1	24	102	22	53	**112**	88	46	3	0	453
Mongalla	1¹⁄₁₂	0	21	110	97	110	166	90	**195**	80	144	7	6	912
Lado	1¹⁄₁₂	0	0	27	136	87	151	**218**	129	123	57	20	2	950
Gondokoro... ...	4	5	9	71	90	**175**	110	139	129	139	**144**	52	8	1071
Nimule..	1	0	0	141	48	24	67	**164**	98	134	123	127	38	964
Wadelai	6¹⁄₁₂	18	18	113	119	**123**	113	104	115	**178**	117	20	25	1063
Lake Albert.														
Butiaba	1	29	6	131	**137**	99	123	29	58	37	**130**	96	90	966
Fort Portal... ...	2¹⁄₁₂	55	41	137	**168**	160	123	106	115	166	**219**	143	49	1482
Lake Victoria.														
Entebbe	6¹⁄₁₂	80	97	174	**233**	167	123	61	70	80	78	**169**	144	1476
Mengo...	7¹⁄₁₂	60	110	114	**187**	122	72	85	85	98	**133**	92	42	1197
Jinja	3	89	66	96	**210**	117	79	43	121	62	94	**103**	97	1177
Mumias	8	75	99	129	**239**	206	208	173	146	**186**	146	143	94	1844
Kisumu	6	70	118	106	**162**	127	80	42	50	70	97	142	**152**	1216
Masaka..	2¹⁄₁₂	71	127	109	**234**	160	17	26	62	101	**154**	128	118	1307
Mbarara	3	89	81	**179**	93	92	46	31	126	185	215	**226**	133	1496
Bukoba	4	96	172	280	**571**	463	54	28	56	62	93	**209**	122	2146
Shirati...	1	91	49	60	**169**	89	42	22	6	26	**76**	34	66	730
Muanza	3	128	117	112	**184**	146	108	78	101	96	192	**237**	92	1521
Tabora...	6	111	104	104	87	21	5	0	0	9	15	85	**122**	663

* Probably too high a mean value due to 630 mm. having been recorded in August 1895.

Table IV.—Difference between Rainfall of 1903 and 1904 in Millimetres.

Place.	Jan.	Feb.	March.	April.	May.	June.	July.	August.	Sept.	October.	Nov.	Dec.	Year.
Khartoum	0	0	0	0	−24	0	+ 16	+ 64	+ 6	0	0	0	+62
Kassala	0	0	0	−2	−20	−17	− 5	− 16	+51	+59	+ 4	0	+54
Khashm el Girba	...	...	...	...	...	−30	− 17	− 44	−14	+37	...	...	[−68]
El Obeid	< no observations in 1903 >						+121	− 95	+31	+ 4	0	0	[+61]
El Dueim	0	0	0	0	−14	+ 9	− 41	− 13	+33	− 2	+ 2	0	−26
Wad Medani	0	0	0	0	+38	−44	− 39	− 25	+25	+ 4	+12	0	−41
Gedaref	< no observations in 1903 >						+ 36	+ 13	−23	+29	+ 2	0	[+57]
Gallabat	< no observations in 1903 >						+ 93	−129	+76	+35	+11	0	[+86]
Roseires	no observations in 1903												
Kodok	0	−2	+9	+9	−24	+59	−50	−96	−146	− 43	0	0	−284
Doleib Hilla	< no observations in 1903 >				+35	−18	+15	−10	− 99	−142	−31	0	[−250]
Nasser	observations October-December 1903 only									− 16	+21	0	+ 5
Asmara	no observations for 1903 received												
Addi Ugri	...	...	...	...	...	+40	+ 47	−115	−32	...	...	...	[− 60]
Chenafena	...	...	...	+ 9	− 82	+29	+ 38	−110	− 5	...	...	...	[−121]
Addis Abbaba	−30	+24	+88	−32	−202	−71	+106	− 76	−25	+25	...	...	[−193]
Wau	no observations in 1903												
Ghaba Shambe	no observations in 1903												
Mongalla	...	...	...	−28	+39	−107	− 81	−82	−17	+33	+ 8	+11	[−224]
Gondokoro	+ 1	+32	+92	−14	−41	− 86	−157	+41	− 1	−45	+29	+ 4	−145
Nimule...	no observations in 1903												
Wadelai	−15	+36	− 1	+48	− 7	−142	+ 41	+44	−65	−55	+133	+ 8	+ 25
Butiaba	no observations in 1903												
Fort Portal...	...	+ 53	+143	−156	− 7	−234	−28	+ 55	− 27	+79	− 39	+ 69	[− 92]
Entebbe	−125	+ 73	− 85	− 49	+ 67	−123	−88	+ 76	− 54	−17	+108	+ 47	−170
Jinja	− 97	− 1	+ 30	...	− 72*	− 90	...	+ 64†	− 24	−39	+104	+ 73	− 52
Mumias	−158	− 10	− 91	+ 80	− 27	−189	−87	+118	−148	−43	− 18	0	−573
Kisumu	−145	− 95	− 61	− 80	− 74	−215	+16	+ 99	− 53	−62	+126	−137	−681
Masaka	...	...	− 50	− 16	+164	− 7	−18	− 24	− 76	− 9	+ 34	+ 82	[+ 80]
Mbarara	...	+153	...	...	+133	− 85	+ 5	+235	+ 96	+73	+134	+178	[+922]

* April and May together. † July and August together.

\+ Indicates that the rainfall of 1904 was greater than that of 1903. — Indicates that the rainfall of 1904 was less than that of 1903.

Considering Table II together with Table III it will be seen that in January on the lake plateau the rainfall was rather below the average as judged by Kisumu, Mumias, and Entebbe, the three stations having the longest series of observations, but as is normally the case no rain fell at other stations to the northward.

In February most of the plateau stations, Mbarara, Kisumu, Mumias, Jinja, Entebbe, and Fort Portal are slightly deficient, but further north the early rains at Wadelai and Gondokoro are somewhat heavier than usual; still these only represent the occasional rainstorms which occur before the commencement of the proper rainy season.

In March the plateau rains were up to the average as given in Table III and also those of the southern part of the Bahr el Jebel, while the light rains extended as far as the Sobat. In Abyssinia Addis Abbaba received 117 mm., but this was from its position near the top of the eastern escarpment of the tableland, for the southerly winds had as yet only reached the plateau of Kaffa to the north of lake Rudolph.

In April the lake plateau seems on the whole to have been somewhat deficient in rain, Mumias, Jinja, and Fort Portal were below the mean value though the other stations fully reached it; the upper Bahr el Jebel area shows but little difference from the mean values, and the light rains extended in this month to El Obeid. In Abyssinia owing to the absence of rainfall stations in the basin of the Blue Nile we can only deduce the variations in the rainfall from the river gauges which will be discussed later.

A communication from Egypt dated April 26 and published in "The Times" of May 6, 1904, stated that unusually violent north winds were reported from the stations on the White Nile, and added, that the rareness of these phenomena at this season gave grounds for predicting heavy rain at no distant date and in consequence a full and early Nile flood. Whoever gave this opinion was mistaken both in his data and the conclusion that he drew from them. The winds at Dueim in April were somewhat stronger than in 1903 but not especially high and being only estimations and not actual measurements too much reliance should not be placed on them; observations only exist for 1901-1904 so that it is too soon to say with any accuracy what the mean conditions are.

The wind direction was also normal as may be seen from the following table in which the gradual increase of southerly winds is shown. The barometric minimum at this time of year probably lies over the country south of the Sobat, and it is difficult to see how the force of the north-east trade wind can be a proof of unusual strength of the moisture-laden southerly winds which bring the rain.

Winds at Dueim, lat. 13°.59′ N.

March, 1904.

Wind directions observed.

Hour.	N	NE	E	SE	S	SW	W	NW	Calm.	Mean Force 1—10
8 h.	1·5	...	...	1·0	...	1·5	5·0	22·0	...	6
20 h.	5·0	...	...	...	...	2·5	5·5	18·0	...	6
Total...	6·5	...	...	1·0	...	4·0	10·5	40·0	...	...
Total for 1903 ...	58·0	2	...	...	...	...	...	2·0	...	5

April, 1904.

Wind directions observed.

Hour.	N	NE	E	SE	S	SW	W	NW	Calm.	Mean Force 1—10
8 h.	0·5	3·0	1·0	4·0	2·0	0·5	1·5	17·5	...	6
20 h.	3·5	4·5	...	3·0	1·0	2·0	...	16·0	...	6
Total...	4·0	7·5	1·0	7·0	3·0	2·5	1·5	33·5	...	...
Total for 1903 ...	37·0	7·0	7·0	0·5	2·5	2·0	2·5	0·5	1	5

May, 1904.

Wind directions observed.

Hour.	N	NE	E	SE	S	SW	W	NW	Calm.	Mean Force 1—10
8 h.	...	3·0	5·0	3·0	2·5	5·0	2.5	10·0	...	6
20 h.	7·0	1·0	4·0	...	...	3·0	...	15·0	...	5
Total...	7·0	4·0	9·0	3·0	2·5	8·0	2·5	25·0	...	...
Total for 1903 ...	19·0	1·0	3·5	11·0	11·0	6·5	7·0	...	3	4

In May on the lake plateau rain was rather above the average causing the maximum at some stations to occur in this month instead of April; the upper Bahr el Jebel received an amount which was near the average, as also was that on the lower Sobat and at Kodok. Addis Abbaba was below the average of May, and the stations of the Sudan plains show no marked excess.

There seems to have been a general idea at the beginning of June that the prospects of the Nile flood were good, though it is difficult to see on what they were based. As we have seen, the rains in Uganda and the southern Sudan up to the end of May were normal or rather below normal but there was nowhere any marked indication of excess. Sir W. Willcocks wrote * "Egypt has had a very good supply this year; . . . . . the Atbara and the other rivers are coming down fairly early, so that all anxiety about want of water may be dismissed for 12 months"; this was too sanguine a view as in May the main rains have not yet set in, even in southern Abyssinia, and the most that it seems possible to deduce from the meteorological conditions of this month is whether they are favourable or unfavourable to the further development of the Abyssinian rains.

In June interest centres rather in the Sudan plains and Abyssinia than in the plateau of Uganda where the rains are decreasing. On the Bahr el Jebel rainfall was deficient, the totals for Wadelai, Gondokoro and Mongalla taken together being only one third of the mean value. On the Sobat, at Kodok, Doleib Hilla, and Nasser the amounts were about normal but Wad Medani, Kassala and Khartoum were below the average. In Abyssinia, Addi Ugri in the north and Addis Abbaba in the east, are the only stations which have the results of previous years as a means of comparison, and the latter was below while the former was above the mean.

July was still slightly in defect on the Bahr el Jebel, while in Abyssinia the rain increased at Addis Abbaba, being about normal at Addi Ugri.

In August which should be the month of heaviest rainfall in Abyssinia there was a rapid falling off, Addi Ugri only recording 0·63 and Adis Abeba 0·51 of the average amount; stations on the plans show little deficiency but that of the rains on the high tableland affected the Blue Nile severely.

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* *Egyptian Gazette*, June 11, 1904.

Taking from Table III the mean rainfall at Keren, Addi Ugri, Gondar and Addis Abbaba for the months May to September we have for the distribution of the rain which supplies the Nile flood:—

MEAN RAINFALL IN MILLIMETRS.

	May.	June.	July.	August.	September.
Keren	25	107	106	300	78
Addi Ugri	43	67	148	178	34
Gondar	67	122	290	372	103
Addis Abbaba... ...	89	158	298	270	180
Mean...	56	114	210	280	99
Percentage ...	7·5	15·0	27·5	37·0	13·0

If therefore the August rainfall was deficient this year to the extent of about 0·4 which seems a fair deduction from the river gauge data, the water supply of the Nile flood was thereby deprived of about 14 per cent of its volume in that month alone, and this is a large amount when it is remembered that the volume of the flood of 1899, one of the lowest recorded, was 0·63 of the volume of an average flood as derived from the gauge records at Aswan.

September is normally a month when the rain falls off rapidly and it is seldom if ever that the September rains of Abyssinia are heavy enough to make up a really serious deficit in the August rains. This year they seem to have been a little below the average in Abyssinia, and slightly above it on the Sudan plains, Kassala's record of 127 mm. being probably a high one.

The October rains were light in the Sudan but on the Bahr el Jebel as the rain-belt returns the precipitation increases and this year it was slightly above the average. This was the case also over the lake plateau and the rain on lakes Victoria and Albert was again heavy.

November is the winter month of heaviest rain on the lake plateau from Nimule southwards and in 1904 was above the average so than the lakes will in all probability remain at a high level through the coming year, as the autumn rains are much more effective in this that the April-May rains. It is interesting to note in this connection that the same conditions have affected lake Rukwa in lat. 8° S. which was dry

in the middle nineties but has risen very greatly in 1903 and 1904 and is now at a high level. *

The December rainfall is restricted to the lake plateau and especially the southern part of it where last year the fall was, like that of November, above the average.

The effect of this rainfall on the Nile may next be studied.

In 1903 a moderate rainfall on the Abyssinian tableland provided a fair flood, and since this rainfall continued late and heavy in the autumn months the Blue Nile and the Sobat fell more slowly than they would otherwise have done, as the Abyssinian springs were able to furnish a larger supply in the spring and early summer, so that the low stage of the river in 1904 was fairly good, the gauge readings at Wadi Halfa differing but little from the mean of 15 years as shown in the following table:—

MEAN DIFFERENCE FROM GAUGE READINGS 1890-1904.

	Metre		Metre
January	−0·16	April	−0·07
February	+0·03	May	+0·03
March...	−0·06	June	+0·07

although the flood of 1903 had not reached the average volume of the last 35 years, but was about 11 per cent below it. †

Lake Victoria had risen considerably in 1903 and heavy November rains had brought it to the level of 0·90 metre (Kisumu gauge) in December (Plate I.).

The Albert lake had likewise risen 0·83 metre between March and November 1903 ‡ and by the end of December it had probably risen some few centimetres more. On January 1st 1904 the Wadelai and Gondokoro gauges were 1·90 metre and 1·62 metre respectively, compared with 0·76 metre and 0.74 metre on the same date of the year before.

Generally then it may be said that lakes and rivers were at a very fairly high level at the beginning of the year.

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* "Globus," vol. 87, No. 5, p. 84.

† Considering the volume of water passing Aswan between July 1 and October 31, as deduced from the gauge readings, to represent the flood.

‡ "A Report on the Basin of the Upper Nile," Cairo, 1904, p. 81.

Lake Victoria remained steady throughout January and February but commenced to rise about the middle of March when the rainy season set in. This continued throughout April and May until the early part of June when the level began to fall slowly and continued to do so until the middle of November; the autumn rainy season then caused the lake to rise until the end of the year. This variation of level however will have had no effect on the supply which reached the Bahr el Jebel since the action of the lake and swamps of Choga is to moderate any variations in the volume discharged at the Ripon falls, and deliver a practically constant volume at Mruli from season to season and from year to year since the Mruli-Foweira reach of the Victoria Nile shows hardly any rise of level even in the rainy season.

Gauge readings were commenced on the eastern shore of the Albert lake at Butiaba on February 19 and until March 10 the lake was falling from its maximum of the previous December; after this it rose slightly in March and April, remained almost stationary in May, June, and July, when evaporation and discharge balanced the supply received, but began to rise with the later rains and continued to do so up to the last week in December.

MEAN LEVEL OF ALBERT LAKE 1904.

	Metre		Metre		Metre		Metre
January ...	...	April ...	1·67	July... ...	1·68	October ...	1·74
February...	1·72	May... ...	1·68	August	1·70	November...	1·80
March ...	1·66	June ...	1·68	September.	1·74	December...	1·85

Here as in the Victoria lake the early rains of April which are followed by the dry season June and July appear to have a much feebler effect than the autumn rains in determining the mean level of the lake for the coming year.

In the case of the Albert lake this is increased by the heavy rainfall in Acholi, the hilly region lying east of Wadelai and north of the Murchison falls, which must furnish a large supply to the Victoria Nile below Foweira and to which the flood rise of this reach is due; taking the rainfall of Wadelai and Nimule as a guide there must be heavy precipitation in this area up to the end of November.

The gauge curves for Wadelai, Gondokoro, Mongalla, and Ghaba Shambe are given on Plate II and by the aid of them the effect of the

rainy season on the Bahr el Jebel can be seen. The Wadelai curve is very different from that of 1903 which showed many subsidiary rises and falls, so that it is questionable whether it records truly the variations of water level. The gauge is placed in a brick-lined well * and it appears as if the connection between the well and the river had been sanded up, and from time to time was partially re-established; unless this is the case the large rise on August 7 is difficult to understand since the lake level is stationary.

Gondokoro furnishes a complete series of readings for the year † which show well the weakness of the rains in the early part of the summer, as in 1903 the river level rose steadily from the beginning of May until the end of July, about 0·80 metre in all, whereas in the present year in spite of occasional rises lasting for a few days the level was the same at the end of June as at the beginning of May, and only 0·40 metre higher at the end of July; after August it fell gradually in spite of occasional flood waves coming down.

The Mongalla gauge was twice broken during the year and up to the present the data necessary to connect the later observations with those up to September 29 are not forthcoming. In the early summer the variations of river level closely follow those of Gondokoro until August 3 after which date the Mongalla level remained apparently almost steady though at Gondokoro there was considerable variation. The conclusion is unavoidable that during August and the early part of September the gauge readings were not taken daily and do not therefore represent truthfully the variations of the water level.

Lower down the Bahr el Jebel the rise of the water level is much more regular; the early rises at Gondokoro and Mongalla are not felt, but those of May, June and July are, while the highest level was reached at the end of September, the total range being 34 centimetres. The level in December was stationary which was not the case in 1903, but by the middle of January the fall recommenced; this interruption of the fall of level may have been due to the combined effect of wind action and of the supply from above being sufficient to maintain the Shambe lake at its level, but no proof of this is available; in 1903 the fall of the water level went on continuously.

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* "A Report on the Basin of the Upper Nile," Cairo, 1904, p. 94.

† By an error of reading all levels of the river after December 1, 1903 were read 1 metre too low on the inclined scale, or 0·86 metre vertical so that this correction has to be applied to all readings. In the diagram this has been done.

GHABA SHAMBE

GAUGE READING

	1903-1904		1904-1905	
	Reading.	Fall.	Reading.	Fall.
	m.	m.	m.	m.
November 1	1·92		1·85	
„ 10	1·90		1·78	
„ 20	1·84		1·70	
December 1	1·75	0·17	1·65	0·20
„ 10	1·74		1·65	
„ 20	1·69		1·65	
January 1	1·61	0·14	1·65	0·00
„ 10	1·51		1·65	
„ 20	1·45		1·58	
February 1	1·40	0·21	1·50	0·15

A very valuable record of the south Abyssinian rains is furnished by the Sobat river gauges at Nasser and the American Mission station at Doleib Hilla. The Nasser gauge readings are not yet quite free from doubt as there appears to be one gauge on the river bank and another near the fort which is used when the river is at its highest level so it is the relative rather than the absolute difference of level at various dates which we must consider. Turning to Plate III the first rains on the Kaffa tableland caused a sharp rise in the river about March 10 though even on the 1st a slight rise took place. The former rise is clearly marked, though much modified in range, at Doleib Hilla and Taufikia, while a very slight rise at Dueim on April 3 and 4 may possibly be due to the same cause. Afterwards two other rises at the beginning and end of the month are recorded at Nasser and more faintly shown in the gauge curves of Doleib Hilla and Taufikia. On May 1 the effect of the heavy rains is first felt and from this date the Nasser gauge rises steadily until the end of October, showing that the rains in this part of Abyssinia having once set in continue with sufficient regularity to furnish a steady supply to the Baro river. The regularity of the curve is very noticeable if it is compared with that of Roseires or any other gauge station on the Blue Nile. (Plate IV).

The lower gauges follow the same steady rise as that of Nasser and it is very noticeable how completely the Sobat, as represented by the Doleib Hilla gauge, impresses its character throughout the year on the White Nile; only in the early part of January of this year, 1904, was

the fall at Taufikia somewhat slower than that at Doleib Hilla, the level being presumably maintained by the water held up in the White Nile above the junction; but in December last after a maximum gauge reading of the Sobat nearly a metre below that of 1903, this delay is not noticeable, the amount so held up being much less. * North of Taufikia the rainfall decreases very rapidly from about 800 mm. to 217 mm. at Dueim and 98 mm. at Khartoum, so it is not remarkable that the Dueim gauge is not affected by the local rainfall; but soon after the rise has commenced, this year 48 days after, the rapidly rising flood of the Blue Nile raises the White Nile water level and affects the Dueim gauge so that this gauge no longer represents the variations of rainfall at any place up-stream of it.

As has already been explained there are no rainfall measurements yet available from the central part of the Abyssinian tableland which includes the basin of the Abai or Blue Nile, and those of Addis Abbaba cannot be taken as truly representative of the rainfall which feeds this river; we have then only the river gauges to go by, but from the steep slope of the Blue Nile in its upper reaches, variations in the rainfall and consequently in the run-off, are quickly visible on the Roseires gauge. This and the gauges below it are shown for 1904 on Plate IV and the difference between the Roseires curve and that of Nasser on Plate II is very striking. Nasser is not a great deal further from the Abyssinian plateau than Roseires, though the slope is probably less, but the great contrast is due mainly to the different character of the rainfall in the central and southern parts of the tableland. Actual proof of this is not yet available but the few observations by Cecchi, Michel, Austin and others seem to show that the rainfall in Kaffa, when it has once set in, is of a steady regular type, as distinguished from the bursts of heavy rain with intervening lighter periods which characterize precipitation in the central portion of the country. The main tributary of the Abai, the Didessa, however rises very near the Baro river, or upper waters of the Sobat, in the Seshia mountains, so that we may expect that this river when more fully known will prove to have a regimen like that of the Sobat, that is, an early and steady rise, a maximum in the autumn, and a rapid fall. Michel's account rather bears out this as he records its low stage in 1899 in April and its maximum in September.†

The other main southern tributaries probably are of a similar type, at any rate to some extent, and I would suggest that the sudden rises which project above the mean position of the Roseires curve are due

* This result does not bear out the view expressed by Sir W. Willcocks, in "The Nile in 1904," London, 1904, p. 57.

† "Vers Fachoda." Paris 1900, p. 558.

rather to the northern tributaries from the provinces of Gojam and Amhara. Similar irregularities on the Khashm el Girba gauge curve on the Atbara, which drains an area rather further north, would seem to lend countenance to this view.

The beginning of the annual rise at Roseires took place on May 2, about a week later than in 1903, this being probably due to the Didessa and the southern tributaries. A pause in June corresponded with that of June 1903 and this early rise followed by a fall probably represents the rise on the early part of the curve of the gauge readings in most years. It would seem to be due to an early burst of rains which is followed by two or three weeks of finer weather, and the inhabitants of the Beni Shangul district speak of such a phenomenon as usual, but the meteorological cause of it has yet to be traced. Heavy rainfall seems to have occurred at the end of May on the western slopes of the tableland north of the Blue Nile, which brought down the Dinder in flood and raised the Sennar gauge during the first half of June. Throughout July the rise of the river was well maintained, and the rainfall was probably fair if not almost normal but with the beginning of August it must have almost completely failed in central Abyssinia since the gauge at Roseires fell 3 metres in 17 days; as already pointed out on page 15, this must have been equivalent to a loss of at least 14 per cent of the flood supply and the year's flood proved to be only 0·75 of a mean flood. A few brief rises took place after this but the mean level improved but little until the middle of September when the rainy season ended and the river fell rapidly. A moderate early rainfall and a very marked failure of the August rains gave no opportunity for the Abyssinian springs to be filled, or for the soil to become thoroughly saturated, so that the tributary rivers rapidly ran down, as has already been seen in the case of the Sobat; and before November it was evident that the low stage of the Nile must in consequence be a considerably lower one than the average.

The gauge readings in 1904 at Wadi Halfa bear this out when compared with the mean of the 15 years 1890-1904.

Date.	Difference from mean gauge (in metres).		
	January.	February.	March.
1—5	−0·55	−0·49	−0·53
6—10	−0·49	−0·55	−0·55
11—15	−0·47	−0·55	−0·48
16—20	−0·46	−0·63	−0·47
21—25	−0·46	−0·62	−0·49
26—31	−0·48	−0·56	−0·51

For the northern part of Abyssinia which supplies the Atbara and the Gash, the meteorological stations of the Italian colony of Erithrœa furnish valuable information concerning the rainfall which flows to the latter river, but Addi Ugri is the only station for which a series extending over several years is available. For the Atbara the gauge recently erected at Khashm el Girba (just south of lat. 15° N. and 11 kilometres upstream of Fasher) represents the run-off of the Takazze basin.

This shows the usual rapid rise in June and July and the sudden fall about August 7, rather later than at Roseires but as clearly marked, and here also the readings show no general rise after this date before the middle of September when the end of the rainy season was reached; the failure of the rains therefore extended to northern Abyssinia.

After the drop in early August it is instructive to note that both the Roseires and the Khashm el Girba gauge curves show four marked rises at nearly the same dates which are evidently due to the rainfall increasing all over this part of the tableland about the same time and then being followed by finer weather.

The decrease of the rainfall in passing from the Abyssinian tableland about 1000 millimetres to Rosires 700 mm., Gallabat 900 mm., Gedaref 600 mm., Kassala and Wad Medani 300 mm., is so rapid that data furnished by the few years for which observations exist cannot show if this year's rainfall was above or below the average, and the same applies to all stations of the Sudan plains. A very much larger collection of data is necessary before the rainfall of the plains can be discussed, and even records of the number of rainy days in each month at as many points as possible would be of the greatest possible service in following the distribution of rain, and seeking the factors which control such distribution.

By the aid of a series of widely scattered observing stations and the various river gauges, it has been possible to present a fairly connected account of the rainfall which fed the Nile in 1904, and to show how quickly the gauge readings respond to variations in the rainfall which may in a few days markedly modify the flood.

The Dueim gauge alone, though most interesting from a hydrological point of view, does not represent the rainfall.

Since the amount of the holding up of the White Nile waters by the Blue Nile flood has been realized, the Dueim gauge has been considered as only recording the slow filling of the White Nile valley but when this gauge and that of Khartoum are considered together

they furnish an instructive picture of the interaction of the Blue and While Niles at their junction as shown in the following description. *

"The behaviour of the two main streams of the Nile may be studied by comparing the gauge readings taken at Khartoum 4·5 kilometres upstream of the confluence, and at Dueim 201 kilometres up the White Nile.

From calculations based on the method explained in Appendix IV, of the "Report on the Basin of the Upper Nile," the slope of the White Nile at Dueim was found to be $\frac{1}{100000}$ in flood and $\frac{1}{50000}$ in the low stage, which gives a rise from Khartoum to Dueim of 2 metres in flood and 4 metres at the low stage; consequently, if these slopes are correct, the average range of the Khartoum gauge should be 2 metres more than that at Dueim.

The following table gives the observed ranges in 1902-1904.

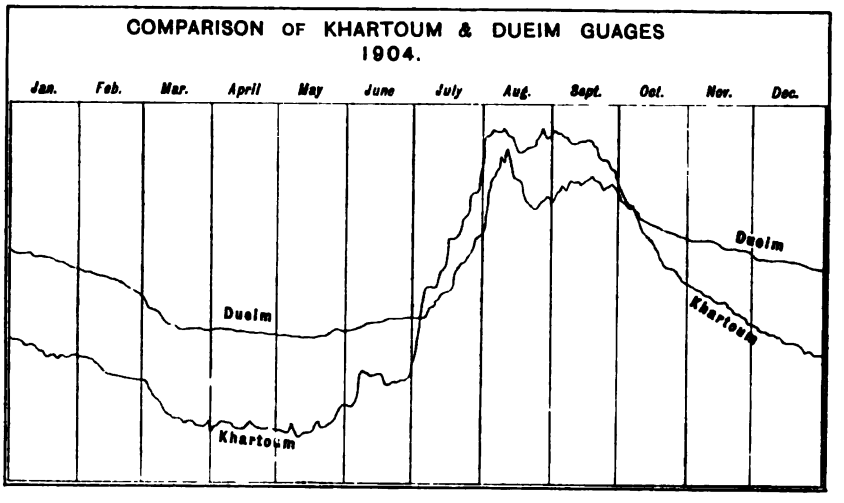
	Dueim			Khartoum			Difference of ranges.
	Max.	Min.	Range.	Max.	Min.	Range.	
1902	3·75	0·49	2·26	5·50	−0·12	5·62	2·36
1903	4·50	0·31	4·19	6·28	−0·28	6·56	2·37
1904	3·60	0·15	3·45	5·64	0·0	5·64	2·19
Mean	...	...	3·63	...	...	5·94	2·31

This gives an excess of 2·31 metres in the range at Khartoum over that at Dueim; but while the curve of readings at the latter station is relatively smooth, that at the former is subject to sudden fluctuations. The absolute range is therefore not the best measure of the mean conditions prevailing, which would be obtained better from seven or ten-day means at full flood and lowest stage. If this is done for both gauges the excess of range at the mouth of the Blue Nile over that at Dueim is reduced to 2·2 metres, which checks the slopes as nearly as can be expected from such data.

The curves of the Dueim and Khartoum gauge readings have been plotted in the diagram below with a difference of 1·7 metres between

* By Mr. J. I. Craig.

the zeros for these two gauges.* Accordingly when the mean slope is $\frac{1}{10000}$ the curves intersect, when it is flatter, Dueim readings lie below the others, and when steeper, Dueim readings lie above Khartoum readings as plotted in the diagram.



We are now in a position to compare the action of the two branches. During the low stage the White Nile dominates the other as is shown by the production of several small "waves" at Khartoum *after* their passage past Dueim. In May the Blue Nile begins to rise, which it does at first in a very irregular manner, so that the curve for Khartoum presents a series of waves at this period, but a comparison of the curves shows that these waves have not the slightest influence on the Dueim gauge reading until the mean slope has fallen to about $\frac{1}{10000}$, after which they are reproduced at Dueim, frequently with remarkable fidelity, but from two or three days later. That the Blue Nile has no effect on the gauge readings at Dueim until it has risen 2 metres more than the White Nile at Dueim receives additional support from the remarkable shape of the curves in June-July 1904. It will be seen that the White Nile hardly rose at all till the 8th of June although the Blue Nile was rising extremely rapidly ; about that date the slope reached the critical value and at once the White Nile began to share

* The comparison of 150 simultaneous readings during the low stage in each year from 1902-1904 shows that the mean reading at Dueim corresponding to zero at Khartoum is 0·3 m. The difference in the level of the respective surfaces is then 4 m. The difference between the levels of the two zeros is accordingly 3·7 m. By plotting the curves with a difference of 1·7 m. in their zeros, the critical slope is thus indicated by the intersection of the two lines.

in the rise. Much the same phenomenon occurred in 1903 when the critical slope was attained on August 3, the gauges rising by almost exactly the same amount day by day for over a month; at this point a lag of one day at Dueim is found.

When the river begins to fall at Khartoum the effect is not felt to the same extent at Dueim, for by that time the upper White Nile is approaching its maximum and the flow of water past Dueim is maintained by the increased supply and the reduction of the level of the water stored in the valley above Dueim.

The remarkable rise and sudden drop at Dueim between August 5 and August 14 1904, seems undoubtedly to be due to the effect of the wind. At Dueim between these dates strong or fresh winds were registered daily while at Khartoum very light winds or calm prevailed. Further, on the 7th and 8th the wind direction was slightly upstream, which is quite unusual at this season."

The rains then of 1904 were generally below the average though in Abyssinia there was an improvement in July followed however by a large deficiency in August which seriously affected the volume of the Nile flood. There was no subsequent improvement and the low stage of the river is lower than usual in consequence. The equatorial lakes have maintained their high mean level rather, it would appear, from the meteorological conditions in July and August having been less favourable than usual to evaporation; rainfall which was somewhat deficient in the earlier part of the year, was above the average in the autumn.

LAKE LEVE

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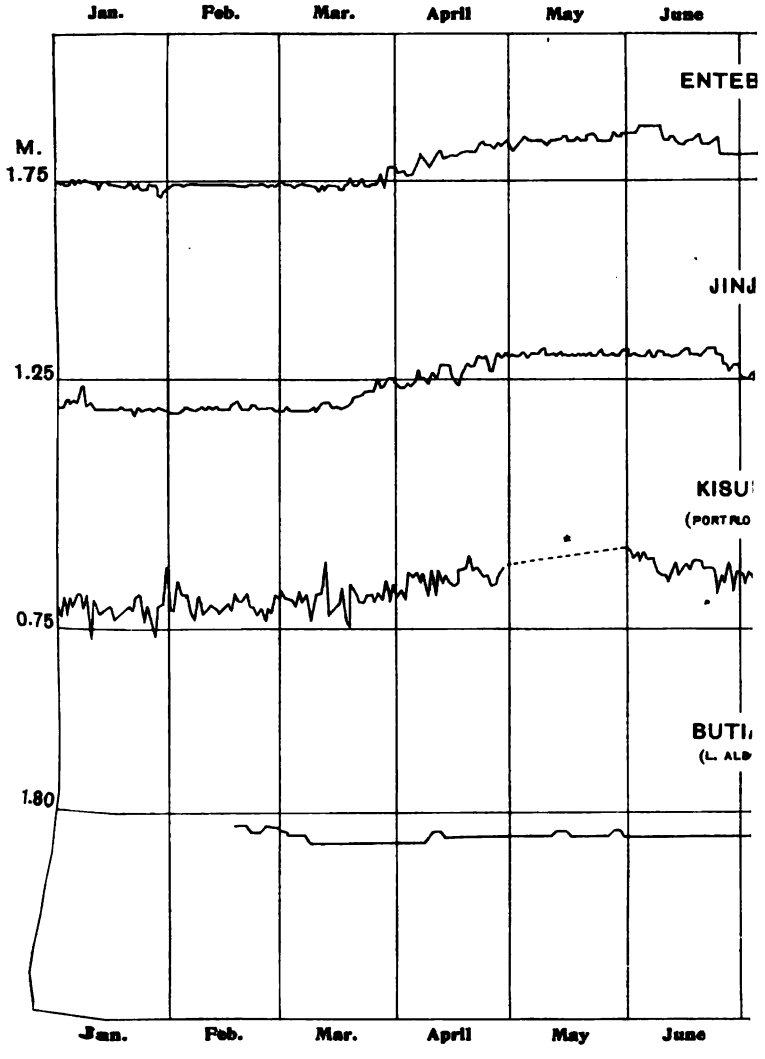

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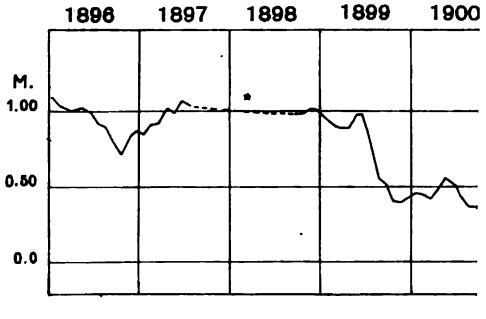

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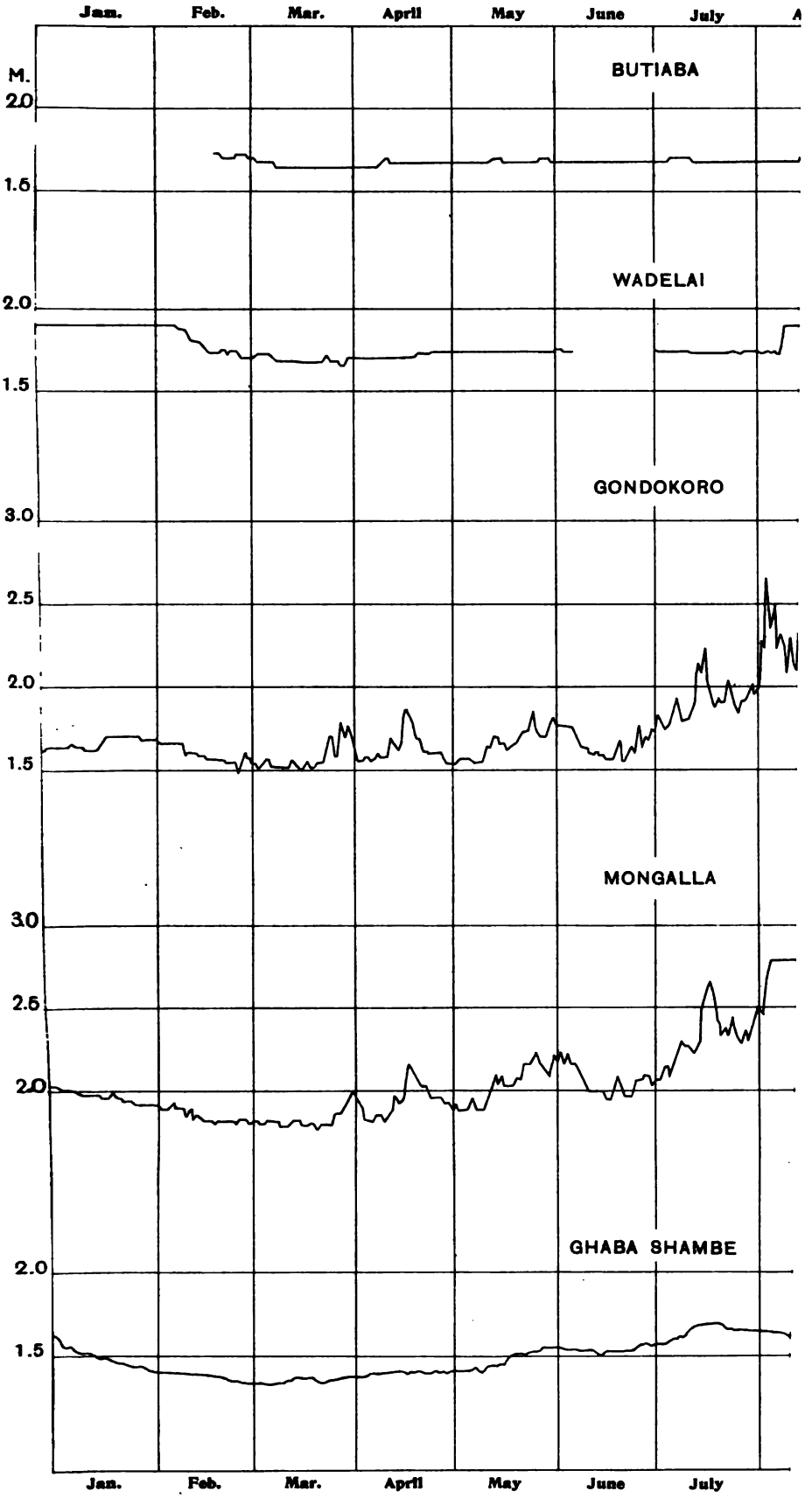

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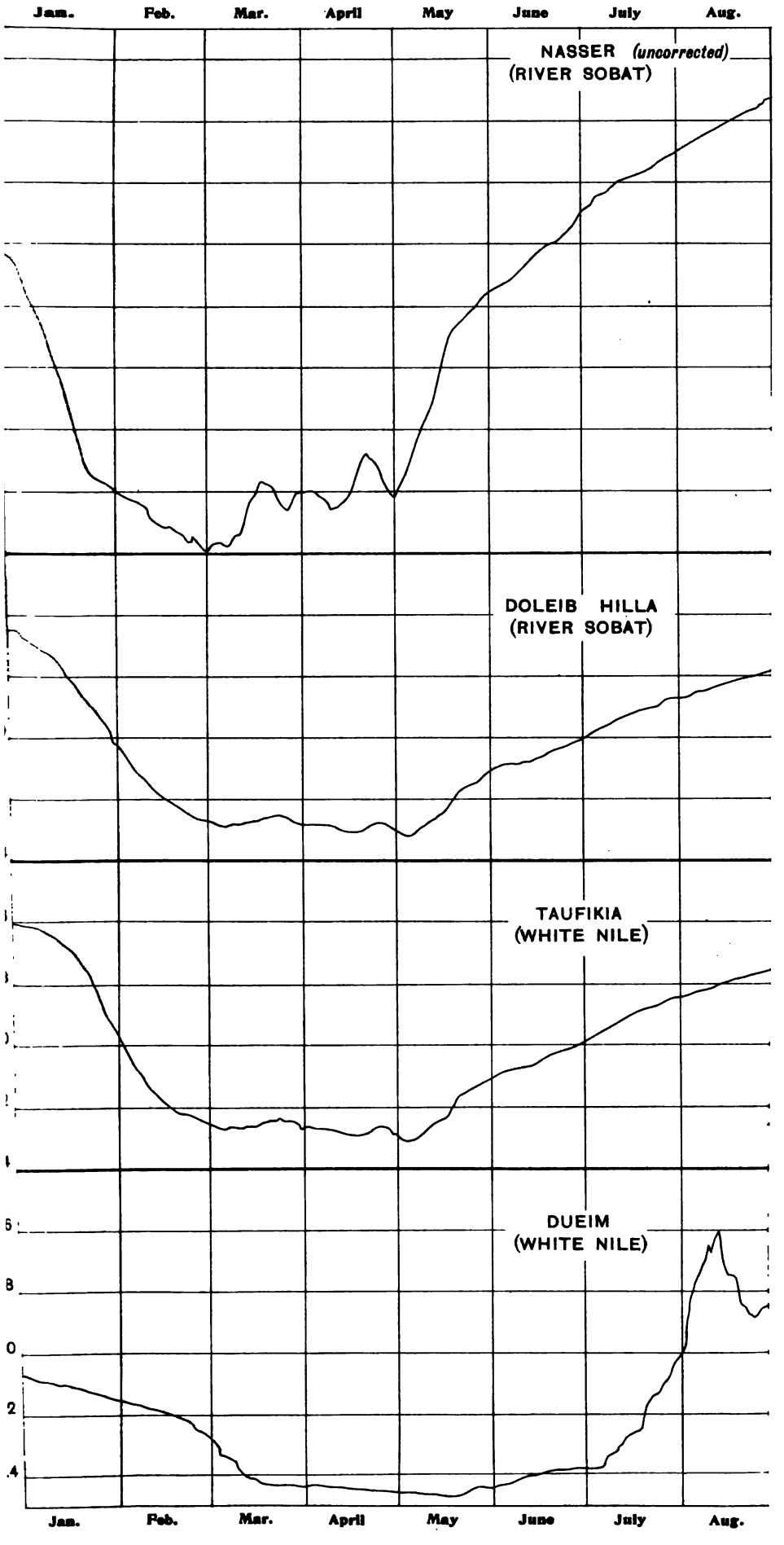

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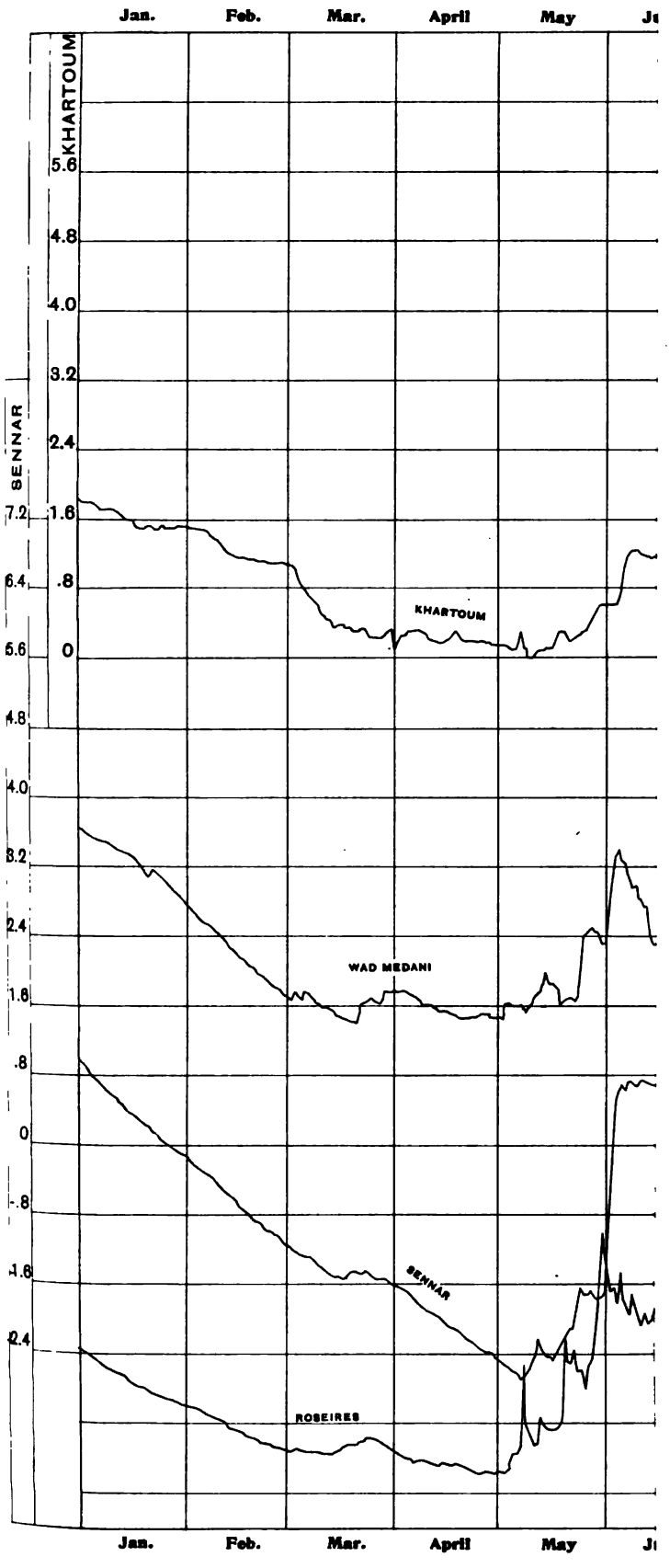

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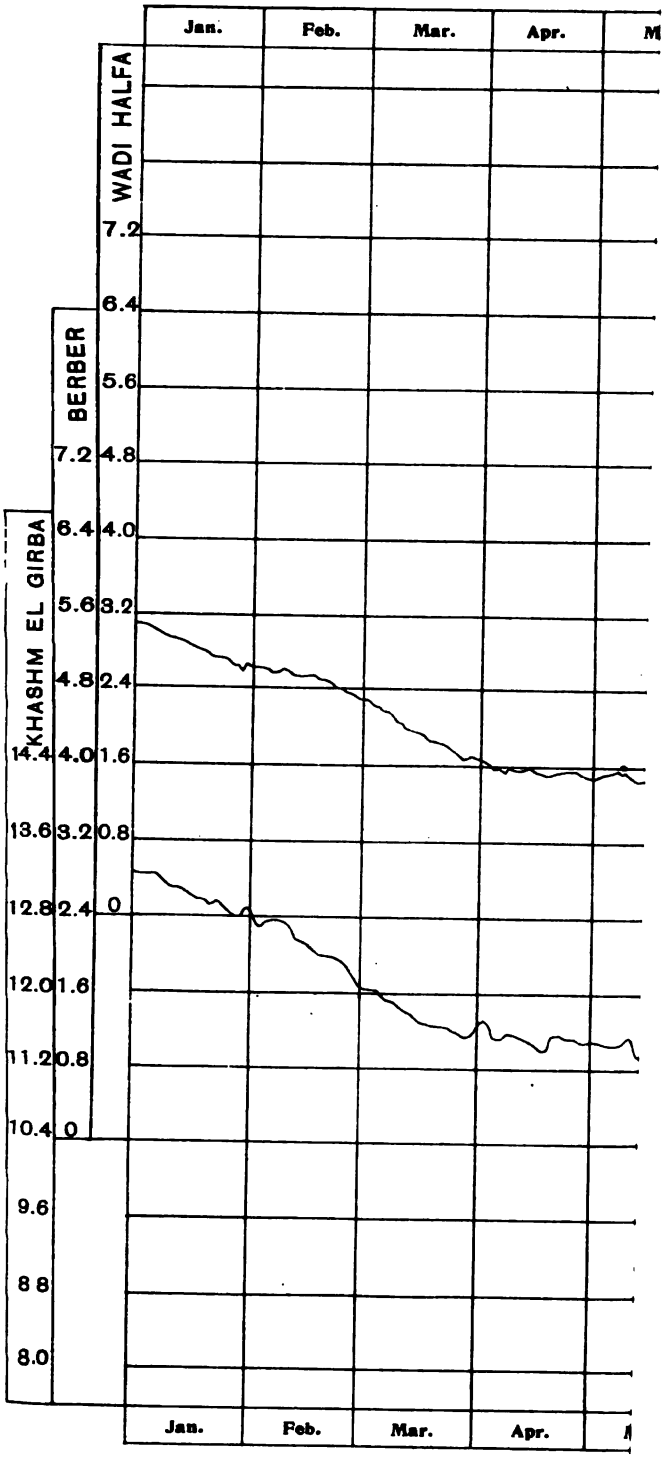
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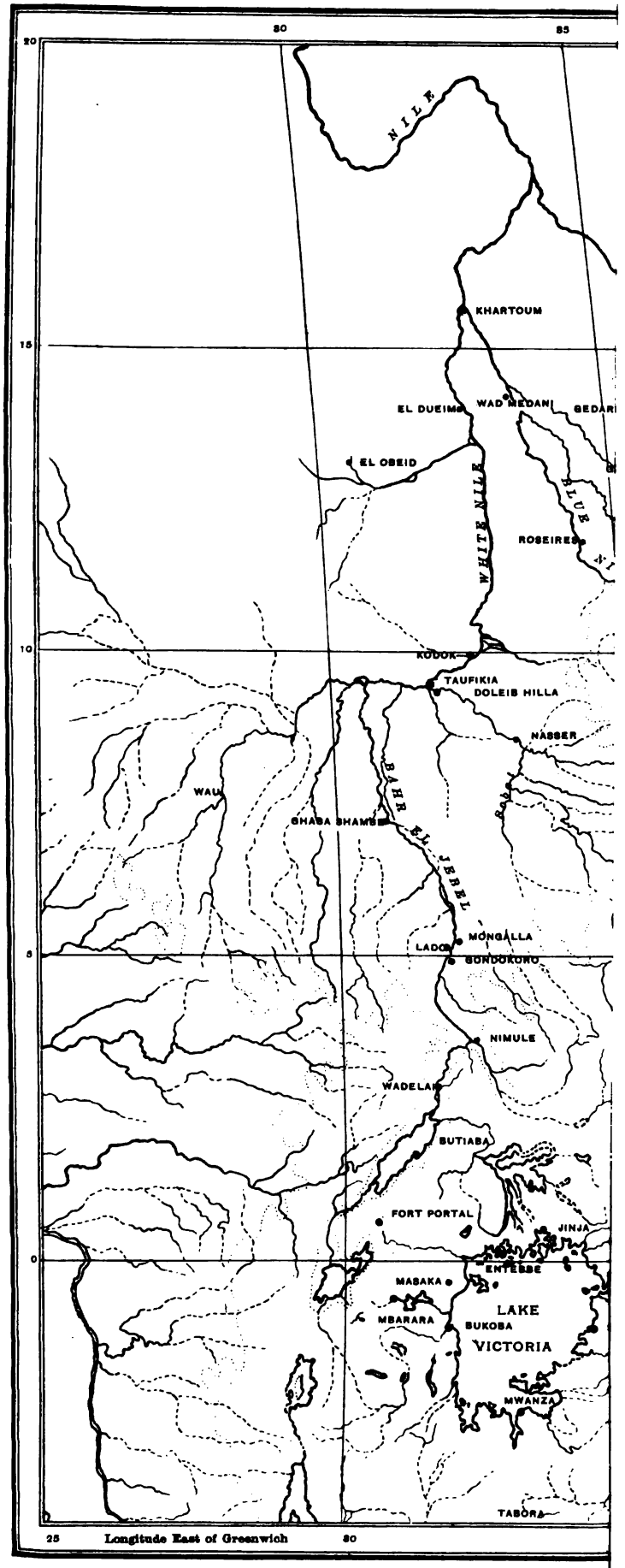

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MINISTRY OF FINANCE

SURVEY DEPARTMENT,

EGYPT.

THE RAINS OF THE NILE BASIN

IN 1905

BY

CAPTAIN H. G. LYONS,

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CAIRO

AL-MOKATTAM PRINTING OFFICE N. 105

1906

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W. J. Hussey
9.18.39

LIST OF PLATES

I. Basin of the Upper Nile scale 1 : 7, 500,000

II. *a.* Mean Monthly Rainfall. January — April

b. ,, ,, ,, May — August

c. ,, ,, ,, Sept. — December

III. Lake Victoria levels

IV. Lake Albert, and Bahr el Jebel gauge readings

V. Sobat River gauge readings

VI. Bahr el Ghazal and White Nile gauge readings

VII. Blue Nile gauge readings

VIII. River Atbara and Nile gauge readings

IX. Comparative diagram of Nile floods

INTRODUCTION.

In 1905 the collection of data concerning the rainfall within the Nile Basin was extended more widely, and a number of new rain-gauge stations were established. Besides this, a number of posts throughout the Sudan, at which no measurements of the rainfall are made, furnished fortnightly returns showing the days on which light, moderate, or heavy rain fell. Though these returns do not lead as yet to any definite conclusions, it is hoped that they will gradually furnish material by means of which the distribution of rainfall on the Sudan plains may be studied.

The following table gives the number of stations at which observations have been made in 1904 and 1905 though at some of them they were only commenced in the summer of 1905.

TABLE I.

	Number of stations	
	1904	1905
Egypt	16	16
Sudan plains and Blue Nile...	10	21
Sobat, Bahr el Jebel and Bahr el Ghazal ...	8	10
Eritrea and Abyssinia	4	7
Lake plateau	8	10
British East Africa (1)	—	14

Besides these stations where the rainfall was regularly measured, rainy days were recorded at 44 stations distributed through 10 districts (see p. 26)

(1) Not used in 1904 as not within the Nile basin, but important for showing the variation of the rainfall in different areas.

TABLE II.

DISTRICT	N°. of stations
Dongola	1
Berber	4
Suakin	6
White Nile	3
Bahr el Ghazal	8
Blue Nile	6
Sennar	5
Khartoum	2
Kordofan	8
Kassala	1
TOTAL	44

The position of stations is shown on Plate I.

The Egyptian and Sudan stations at which the rainfall is measured only number 31, the remainder being situated in the neighbouring territories of Eritrea, Uganda, British East Africa German East Africa and British Central Africa, from all of which information has been most generously supplied.

Captain Tancredi of Addi Ugri has sent much meteorological information from Eritrea and the Captain of the Port has done the same from Massaua. The Director of the Scientific Department of Uganda and the Director of the Agricultural Department of British East Africa have contributed rainfall and other data both in the from of monthly returns and of telegrams in the early summer when the development of the rains in the southern Sudan was much delayed. From Dar es salam in German East Africa the weekly rainfall totals published in the Deutsch-Ostafrikanische Zeitung have been sent and have been of much interest, though the inland stations are more important for the purpose of judging the northward movement of the rains, but naturally in view of the great distances to be traversed, it is impossible as yet to get information from such stations in time to utilize it. This was the first year that an attempt has been made to collect information from a wide area and to deduce from it the probable development of the East African Monsun in its northern

extension, and much study is still necessary before it can be said precisely what information is more useful and what weight should be given to such evidence as excess or deficiency of rain in different areas. The same is true of other meteorological factors which have been less observed, and the effect of which is consequently less known. Dr. G. Walker F. R. S., the Meteorological Reporter to the Government of India, telegraphed weekly the deviations of the mean barometric reading from the normal for Mauritius, Seychelles, Zanzibar and Aden, which were of the greatest service for comparison with the pressure deviations of Egypt and the Sudan. That the experience gained in 1905 should lead to a reliable basis for forecasting the Abyssinian rainfall, would be too sanguine a view to adopt, but a careful study of the meteorological conditions which have prevailed for the past 15 years over Africa to the north of lat. 10°S.,[1] supplemented by the yearly increasing data, both meteorological and hydrographical, may fairly be expected to throw light on this most interesting and important problem.

It may be said that on the whole the rainfall was everywhere deficient; the volume of the Nile flood[2] was only 0. 65 of an average flood thus adding another year to the long series of low floods which has now continued for 10 years, only two of these having slightly exceeded the average, while the other eight have been much below it.

TABLE III.

YEAR	Ratio to an average[3] flood.	YEAR	Ratio to an average[3] flood.
1891	1.01	1899	0.63
1892	1.20	1900	0.89
1893	0.99	1901	0.87
1894	**1.22**	1902	0.63
1895	1.15	1903	0.89
1896	1.06	1904	0.75
1897	0.89	1905	0.65
1898	1.07		

(1) This has already been commenced.

(2) Considered as the volume passing Aswan between July 1 and October 31.

(3) Average of 34 years 1869-1903.

The rainfall of 1905 will be treated under three heads; firstly, the amounts of rain which were measured at different stations, and the number of rainy days at others where no measurements were made, secondly, the effect of the rainfall as shown by the lake and river levels, and thirdly, the general meteorological conditions which existed over the Nile Basin and part of the surrounding region, together with the estimates of the probable character of the Abyssinian rains which were based on them.

In order to understand properly the seasonal variation of the rainfall, the relative positions of the equatorial low pressure belt and the high pressure areas to the north and south of it in the different months must be borne in mind. In this central area of low pressure there is an ascensional movement of the air. As this air flows upwards and outwards, its place is taken by air which flows in from the high pressure areas to the north and south, as the north-easterly and south-easterly trade winds. This ascensional movement is most marked where the heating effect of the sun is greatest, which will be where the sun is in the zenith at noon.

In January the thermal equator is far to the south of the geographical one and the sun is in the zenith at noon between 22°.58′S. and 17°.14′S., while the line of low pressure lies rather further to the north[1]. The heaviest rainfall is now in the neighbourhood of lake Nyassa, and lighter rain falls as far as lake Victoria, while it may become heavy whenever the south-east trade winds strike high hills, and the air is forced to rise. Over all Egypt and the Sudan this month is rainless, except in the northern Delta where the cyclonic storms of the Mediterranean furnish a moderate rainfall, and along the west shore of the Red Sea where there are also winter rains, but these last are not within the Nile Basin.

In February the sun is overhead at noon between lat. 16°.57′S. and 7°.46′S., while the low pressure belt has moved northwards; the heaviest rainfall is in the neighbourhood of the north of lake Nyassa and the south of lake Tanganika.

In March the noonday sun is vertical between 7°.23′S. and 4°.21′N. and heavy rainfall occurs west of lake Victoria while there is a marked increase all over the lake basin and in northern Uganda, and first showers fall in southern Abyssinia.

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(1) Compare Herbertson. "The distribution of rainfall over the land". Royal Geog. Soc. London, 1901. Also Plates II. a, b, and c.

In April the sun is between lat.4°.44′N. and lat.10°56′N, while the low pressure area lies over the southern Sudan. Rainfall is heavy over the lake plateau, while the first rains begin on the Bahr el Jebel, the Sobat and southern Abyssinia.

In May the zenithal midday sun lies between lat. 15°.14′N. and lat. 22°. 0′N.; the low pressure has moved further north, and rainfall is heavy on the lake plateau, the southern Sudan, and southern Abyssinia, while it is beginning in northern Abyssinia.

In June the sun reaches its greatest declination north and begins to return southwards; the low pressure area includes all the Sudan plains where the rain is heavy, while on the lake plateau it has materially diminished. On the Abyssinian tableland it is increasing rapidly being already very heavy in Kaffa and Wallega, south of the Abai river.

In July the sun is in the zenith at noon at 23°. 5′N. in the beginning and at 18°. 10′N. at the end of the month. Low pressure lies over the Sudan and the minimum is situated near Suakin-Berber-Khartoum; rainfall has diminished greatly on the lake plateau where the dry season with its rapid evaporation has set in; on the Bahr el Jebel the rains have moderated somewhat, but on the Abyssinian tableland and in the northern Sudan they are heavy.

August is very like July though the sun's north declination has considerably decreased and by the end of the month it is in the zenith at noon in lat. 8°. 29′N. The equatorial rain-belt has also moved southwards, but over the whole Sudan and the Abyssinian tableland the rains are normally at their maximum.

In September the conditions change rapidly as the sun is zenithal at noon between 8°. 7′N. and 3°. S.; atmospheric pressure rises rapidly over the Sudan and Abyssinia and the rains decrease, so that by the middle of the month the rainy season is considered to be at an end, except on the southern part of the Abyssinian tableland, on the upper reaches of the Bahr el Jebel, and the northern extension of the lake plateau where it is still heavy. Near the lakes the rainfall increases again as the rain-belt returns southward.

By October dry hot weather has set in over most of the Sudan though rain still falls on the Bahr el Jebel and heavily in its southern part. The sun has passed the equator and is zenithal between 3°. 23′S. and 14°. 17′S. Rain increases over all the lake plateau and is heaviest on the hills of northern Uganda and round the Albert lake.

By November when the sun is in the zenith at noon between

14°.36'S. and 21°.45'S rainfall is heaviest over the whole lake plateau forming the autumn rainy season of this part; from the high altitude of the country in the north of Uganda as far as lat. 3°.N. rain is still falling heavily there though it has practically ceased in the southern plateau of Abyssinia, while on the Sudan plains no rain now falls.

In December the conditions are almost the same as those of January, except that the rainfall on the lake plateau is heavier; the sun is at its extreme southern limit and the whole of the basin north of lat. 1°.N. is practically rainless. The heaviest rainfall has moved south to the Tanganika-Nyassa area and Tabora, 150 kilometres south of lake Victoria, is now receiving its heaviest rain. On the western shores of the Red sea the winter rains have recommenced, and also on the Mediterranean shores of the Delta.

This oscillation of the rain-belt is clearly shown in Plates II a,b and c, and also in Table IV where the mean monthly rainfall is given for about 57 places in the Nile Basin and for about 22 more which are situated near it. For many of these the observations extend over two or three years only and consequently are of little weight in furnishing mean values, but they, as well as the more reliable values, illustrate the advance of the rains northward in the early summer and their return in the autumn across the aquator

On the basis of this table maps of the mean monthly distribution of rainfall have been constructed. (Plates II a,b,c.) They only roughly indicate to the true distribution since the proportion of stations to the area represented is so small, but the regular march of tropical rains, and the absence of high mountain ranges in the region under consideration enable a closer approximation to be made than would be otherwise possible with so scanty a collection of data.

In the south-west there is much uncertainty in drawing the lines of equal rainfall on account of the almost complete want of rainfall data.

Though a large area of the Nile Basin is shown on Plate II. as having a fairly copious rainfall of 100 mm. a month and upwards for from three to four months of the year, the fact should not be lost sight of that the whole run-off of the lake plateau and the catchment basins of the Bahr el Jebel, the Bahr el Ghazal and the Bahr el Zaraf is represented by from 350 to 450 cubic metres per second of water immediately up-stream of the mouth of the Sobat river. The immense loss of water by evaporation in lake Choga and in the marshes of the Bahr el Jebel and the Bahr el Ghazal has been already demon-

strated (1), so that a brief mention of it only is necessary here. If 400 cubic metres per second be taken as the mean volume discharged throughout the year immediately up-stream of the junction of the Sobat with the White Nile, then as the whole catchment area up-stream of this point amounts to about 1, 111, 400 square kilometres(2) this volume of water is equivalent to 11. 4 mm. over this area in the year. From Plate II. it may be found that the mean rainfall on the whole area of these basins is about 1200 mm. per annum so that the available run-off has dwindled to 0. 95 % at this point. It will be clear from this how unimportant is the rainfall of the equatorial lake plateau as affecting the Nile supply. Variations in the year's rainfall amounting to even 75 per cent. of the mean value cause no variation in the insignificant fraction which finally reaches latitude 9°. 30′N. The 400 cubic metres per second which flows past this point has still 3650 kilometres to flow before reaching Cairo, and if the mean width is taken at 500 metres and evaporation at only 10 mm. per diem, there is a daily loss from this surface equivalent to 20 cubic metres per second. Historical accounts of the Nile being fordable at many places in Egypt in years of exceptionally low supply do not therefore require more than an early fall of the Blue Nile and Sobat.

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(1) Sir W. Garstin. A Report on the Basin of the Upper Nile, Cairo 1904.

(2) Lyons. Geog. Jour. London, August 1905.

BAHR EL JEBEL AND GHAZAL BASIN

STATION	Years	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Bahr el Jebel.														
Wadelai	7 ½	28	19	111	97	**124**	87	99	117	102	**168**	114	34	1100
Nimule	2	2	4	92	52	144	52	122	124	123	**158**	155	40	1068
Gondokoro ...	5	4	9	55	81	**170**	106	132	149	142	144	54	12	1058
Lado	1 ½	0	0	27	136	87	151	**218**	129	122	56	20	2	948
Mongalla ...	2 ½	2	12	56	112	95	141	72	**183**	112	142	44	5	976
Bor	1	—	—	—	—	17	88	83	**148**	**148**	92	69	32	[677]
Ghaba Shambe	2 ½	0	1	0	18	78	42	86	100	**136**	44	8	1	514
Bahr el Ghazal.														
Wau	2	< ...		18 ... >		22	109	172	100	**193**	112	53	54	0 833
						SOBAT BASIN								
R. Baro.														
Gambela ...	1	—	—	—	—	—	—	—	265	**352**	74	141	—	[832]
R. Sobat.														
Nasser	2 ½	2	0	14	14	81	157	146	**194**	97	50	13	0	768
Doleib Hilla ...	2 ½	0	0	36	32	86	121	**155**	149	136	83	39	0	827
						WHITE NILE BASIN								
Kordofan.														
El Obeid ...	3 ½	0	0	6	0	1	24	**108**	110	48	18	0	0	315
White Nile.														
Kodok	5 ½	0	0	2	12	55	127	102	**212**	110	69	3	0	692
El Dueim ...	4	0	0	0	0	14	8	**74**	55	45	4	1	0	201
Geteina	1	—	—	—	—	—	—	—	—	4	—	—	—	—
Khartoum ...	7	0	0	0	0	4	25	24	**34**	10	10	0	0	107

BLUE NILE, ATBARA AND GASH BASIN

STATION	Years	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Blue Nile.														
Addis Abbaba...	6½	9	37	87	79	86	160	**290**	271	171	13	11	4	1218
Roseires	3	0	0	0	0	51	116	**233**	189	148	27	11	0	775
Abu Naama,etc.	1	—	—	—	—	—	—	—	**135**	60	41	—	—	[236]
Singa	1	—	—	—	—	—	—	56	**80**	8	3	—	—	[147]
Sennar	1	—	—	—	—	—	—	121	**132**	38	16	8	0	[315]
Managil	1	—	—	—	—	—	21	34	**97**	39	5	5	0	[201]
Wad Medani ...	4	0	0	0	0	26	49	126	**132**	81	2	3	0	419
Mesellemia ...	1	—	—	—	—	—	—	62	**70**	42	0	0	0	[174]
Rufaa	1	—	—	—	—	—	—	60	**113**	64	0	0	0	[237]
Kamlin	1	—	—	—	—	—	—	25	45	**46**	0	2	0	[118]
Abu Deleig ...	1	—	—	—	—	—	—	46	**96**	47	18	1	0	208
R. Atbara(1)														
Adua	1	—	—	—	—	—	51	236	**289**	209	65	—	—	[850]
Intetshau ...	1	—	—	—	37	68	74	**302**	177	126	0	0	0	[784]
Gondar	3	0	0	0	0	67	122	290	**372**	103	46	14	0	1014
Gallabat	2 ½	0	0	0	1	46	150	191	**247**	143	52	6	0	836
Gedaref	2 ½	0	0	6	0	37	86	**177**	161	107	10	15	0	599
Khashm el Girba	3	—	—	—	—	—	18	102	**105**	59	20	—	—	[304]
Khor Gash(2).														
Chenafena ...	3	—	—	—	6	46	37	111	**145**	37	8	0	0	[390]
Keren	5 ½	0	3	2	9	25	107	107	**300**	79	2	7	0	641
Asmara	1 ½	2	3	16	18	36	62	**117**	114	18	56	—	—	[442]
Addi Ugri ...	8 ½	0	6	13	22	42	66	157	**179**	37	10	9	5	546
Halai	1	—	—	—	—	63	15	114	**154**	4	2	6	0	[358]
Kassala	8	0	0	0	2	7	24	69	**108**	68	17	1	0	296

(1) Lower course of Takazze and Settit rivers.
(2) Lower course of River Mareb.

RED SEA COAST

STATION.	Years	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Aden	5	**27**	6	2	1	3	9	0	1	3	0	3	4	59
Massaua	[3]	22	9	12	**52**	0	0	0	8	8	4	2	24	141
Ginda	[2]	—	43	53	38	—	—	17	67	—	—	13	28	259
Suakin	16	26	10	0	1	1	0	3	5	0	39	91	50	226
Suez	$19\frac{4}{12}$	**7**	3	2	2	1	0	0	0	0	0	1	4	20

THE RAINFALL OF 1905.

South of the equatorial belt there is, as has been shown, a single rainy season corresponding to the months of December, January and February, while moving northwards two rainy seasons are found approximately coinciding with the equinoxes, beyond which again is a single rainy season in July and August. In British Central Africa the first condition is well represented, and at Zomba (lat. 15°.22′.33″ S.) the rainfall has been measured for II years. This single rainy season occurs also in the southern part of German East Africa as far north as Tabora (lat. 5° 1′ S.) beyond which the equatorial region of two rainy seasons and two dry seasons commences and extends to about the latitude of Wadelai (lat. 2° 45′ N.)

At this station there is a long rainy season but a distinct moderating of the rains in June and July may be recognized corresponding to the dry season of stations a little further south. To the north of this there is a single rainy season as far north as Khartoum and the northern frontier of Eritrea, while a few rainstorms travel even further north in the summer months, and may reach Dongola. From the foregoing account of the rains of the Nile Basin for any year it is necessary to commence at the southernmost position of the rain-belt, and thence trace the advance of the rains northward in the second half of the year. Although some 75 stations (Tables V and VI) have been utilized, at the majority of them observations have been made for a few years; at 22 stations only are five or more years of observations available, so that it is not surprising abrupt differences occur between stations in regions where vast areas are unrepresented by any measurements of rainfall. In the upper basins of the Blue Nile and Atbara which supply the Nile flood there is not yet a single place at the which the rainfall is measured, for Addis Abbaba, though near the watershed, lies in the basin of the Hawash.

TABLE VI

Monthly Rainfall in Millimetres in 1905.

A. Stations near but not in the Nile Basin

STATION.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
British Central Africa													
Zomba	211	—	126	3	0	2	2	2	2	28	237	**334**	[947]
German East Africa													
Dar es Salam...	29	26	165	**603**	85	68	50	32	29	10	22	236	1355
Morogoro Tal	77	42	188	**285**	28	10	13	24	26	25	38	—	[756]
Kilossa	9	25	67	**313**	—	—	—	—	—	—	—	—	[414]
Mpapua	118	107	**178**	101	10	0	0	0	0	0	118	142	774
Tabora	**188**	42	165	181	0	0	0	0	0	4	140	182	902
Udjidji	98	**177**	**177**	130	—	—	—	—	3	—	161	100	[846]
British East Africa													
Zanzibar... ...	60	2	125	**775**	259	48	104	66	76	145	71	141	1872
Mombasa ...	5	4	149	**379**	331	81	26	101		—	—	—	[1076]
Takaungu ...	0	0	67	**355**	274	87	170	—	—	—	—	—	[953]
Malindi	6	0	80	309	**351**	133	103	—	—	—	—	—	[982]
Golbanti... ...	12	0	**122**	55	111	—	—	—	—	—	—	—	[300]
Kismayu... ...	0	9	56	10	**121**	29	114	—	—	—	—	—	[339]
Shimoni	0	0	365	**689**	470	67	138	154	—	—	—	—	[1883]
Machakos ...	20	0	**334**	154	77	14	2	3	8	69	**253**	153	1087
Nairobi	36	0	**291**	202	190	32	22	51	30	63	133	102	1152
Kikuyu	15	0	**422**	357	289	38	0	27	—	—	—	—	[1248]
Naivasha ...	57	0	154	**155**	137	10	29	44	64	41	—	—	[691]
Nakuro	41	0	**213**	49	149	39	31	110	66	96	—	—	[794]
Molo	186	3	273	**33**[illegible]	297	7	11	290	225	245	—	—	[1869]
Eldama Ravine	70	4	**155**	89	90	24	35	—	—	—	—	—	[467]

B. STATIONS WITHIN THE NILE BASIN

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Lake Plateau Basin													
German East Africa.													
Muanza	58	19	**187**	142	18	0	0	1	71	69	192	**218**	975
Shirati	57	16	56	147	**205**	38	13	13	30	25	169	**206**	975
Bukoba	104	96	41	**386**	318	24	18	100	7	157	**354**	346	1951
British East Africa.													
Lumbwa	114	12	**225**	189	167	32	115	99	94	107	—	—	[1154]
Mohoroni ...	247	9	282	**348**	239	13	103	60	172	186	—	—	[1659]
Nandi	257	43	**424**	290	349	57	244	181	222	—	—	—	[2067]
Kisumu	129	73	**234**	100	51	42	64	56	58	43	163	**350**	1363
Mumias	106	58	128	154	**232**	89	127	**247**	84	196	246	226	1893
Kericho	160	38	**357**	235	208	61	168	212	193	212	151	**240**	2235
Uganda													
Jinja	62	18	98	100	**104**	12	87	69	77	137	**231**	76	1071
Entebbe	55	18	**239**	138	209	169	144	44	108	165	**194**	187	1670
Sesse Is.	143	93	255	208	**332**	117	135	—	—	—	—	—	[1283]
Lumbuyu Hill	—	—	—	—	—	—	—	—	146	127	**184**	139	[596]
Masaka	84	8	138	**175**	167	23	32	58	29	98	132	**177**	1121
Mbarara	169	114	**483**	137	44	0	0	115	299	280	373	**413**	2427
Butiaba	7	12	131	118	**179**	22	84	165	117	170	**182**	76	1263
Fort Portal (Toru) ...	43	93	**210**	78	"records since May incorrect"					**256**	147	98	[925]

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Bahr El Jebel.													
Wadelai	23	8	49	55	137	30	76	132	98	**153**	97	0	858
Nimule	5	8	42	56	**264**	36	81	149	108	194	183	42	1168
Gondokoro ...	1	7	3	45	148	94	104	**233**	155	147	62	0	999
Mongalla ...	5	3	2	143	64	91	38	158	**175**	139	119	4	941
Bor	—	—	—	—	17	88	83	**148**	**148**	92	69	32	[677]
Ghaba Shambe	0	0	0	12	53	54	120	88	**232**	68	20	2	649
Bahr El Ghazal.													
Wau	0	0	little	25	84	174	94	**266**	146	60	99	0	948
River Sobat.													
Gambela ...	—	—	—	—	—	—	—	265	**352**	74	141	—	[832]
Nasser	2	0	0	22	44	**162**	82	152	120	67	19	0	670
Doleib Hilla ...	0	0	4	2	92	82	109	131	**153**	48	69	0	690
White Nile.													
Kodok	little	little	0	1	26	102	75	77	**182**	148	17	0	628
El Obeid	0	0	0	0	1	64	**162**	105	46	12	0	0	390
El Dueim ...	0	0	0	0	8	23	22	45	**48**	0	0	0	146
Geteina	—	—	—	—	—	—	—	—	4	—	—	—	—
Khartoum ...	0	0	0	0	6	16	8	**75**	4	50	0	0	159
Nile Below Khartoum.													
Merowe.	—	—	—	—	—	—	—	—	114	0	1	0	[115]

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Blue Nile.													
Addis Abbaba(1)	5	7	48	—	—	—	—	—	—	1	44	0	[105]
Roseires	0	0	0	0	65	179	**207**	160	134	66	24	0	835
Abu Deleig ...	—	—	—	—	—	—	46	**96**	47	18	1	0	[208]
Abu Naama etc.	—	—	—	—	—	—	—	**135**	60	41	—	—	[236]
Singa	—	—	—	—	—	—	56	**80**	8	3	—	—	[147]
Sennar	—	—	—	—	—	—	121	**132**	38	16	8	0	[315]
Managil	—	—	—	—	—	21	34	**97**	39	5	5	0	[201]
Wad Medani ...	0	0	0	0	54	99	162	**291**	120	0	0	0	726
Mesellemia ...	—	—	—	—	—	—	62	**70**	42	0	0	0	[174]
Rufaa	—	—	—	—	—	—	60	**113**	64	0	0	0	[237]
Kamlin	—	—	—	—	—	—	25	45	**46**	0	2	0	[118]
Atbara & Gash.													
Asmara (2) ...	2	3	3	26	—	93	99	**117**	25	—	—	—	[368]
Addi Ugri (2) ...	0	15	9	18	70	58	**224**	186	56	39	24	0	699
Chenefena (2) ...	—	—	—	—	31	44	73	**136**	72	—	—	—	[356]
Kassala (2) ...	0	0	0	0	2	30	93	**127**	126	0	0	0	378
Gedaref (3) ...	0	0	8	0	41	112	**275**	64	103	2	42	0	647
Gallabat (3) ...	0	0	0	0	28	168	133	**274**	85	118	6	0	812
Khashm el Girba (3) ...	—	—	—	—	—	23	**173**	81	55	22	—	—	[354]
Egypt.													
Cairo { Abbassia	**16**	1	11	0	0	0	0	0	0	0	0	5	33
Cairo { Giza ...	3	1	3	**10**	0	0	0	0	0	0	0	5	22
Helwan	0	0	**2**	0	0	0	0	0	0	0	1	**2**	5
Port Said ...	24	2	22	0	0	0	0	0	0	3	0	**45**	96
Suez	**18**	1	0	5	0	0	0	0	0	0	0	0	24

(1) Strictly in the Hawash Basin but is not far from the watershed.
(2) Gash-Mareb Basin.
(3) Atbara-Takazze Basin.

The rainfall on the coast of the Delta was heavier than in 1904 since the cyclonic depressions of the Mediterranean passed nearer to the African coast causing cold and rainy weather. Except for the barley crop which is grown on the coast-belt west of Alexandria this winter rainfall is not of importance, though it is counted upon in the north-western delta to provide such water as is needed by cultivators during the short period when the canals are being cleaned.

Delta Winter Rains 1904 in Millimetres.

Month	Alexandria	Mex	Kafr Dawar	Abou Hommos	Atf	Damanhur	Shubrakhit	Teh el Barud	Kafr Bulin	Khatatba	Hosh Issa
January 1904	63	54	41	13	23	20	15	11	16	15	24
February „	12	15	20	34	34	14	17	14	14	8	12
March „	0	1	4	5	4	4	3	3	6	2	0
October „	3	25	45	7	1	4	2	0	0	1	0
November „	65	71	43	29	39	20	13	10	18	2	22
December „	50	61	68	45	52	36	57	30	36	9	46

Delta Winter Rains 1905 in Millimetres.

Month	Alexandria	Mex	Kafr Dawar	Abou Hommos	Atf	Damanhur	Shubrakhit	Teh el Barud	Kafr Bulin	Khatatba	Hosh Issa
January 1905	46	47	28	11	22	8	10	8	5	1	6
February „	16	28	56	22	33	19	14	16	12	2	20
March „	14	15	8	10	30	24	16	16	11	7	18
October „	28	15	35	30	22	18	4	0	0	0	6
November „	7	34	26	4	4	6	0	0	0	0	10
December „	159	151	150	95	71	72	67	37	28	7	45

Month	Alexandria	Mex	Kafr Dawar	Abou Hommos	Atf	Damanhur	Shubrakhit	Teh el Barud	Kafr Bulin	Khatatba	Hosh Issa
Total Nov. - Mar. 1903 - 1904	109	95	70	58	63	44	40	33	44	28	38
Total Oct. - Mar. 1904 - 1905	194	247	248	124	177	111	112	80	82	22	112

On the western shore of the Red Sea the winter rains are of importance though they do not reach the Nile basin. In years of heavy rainfall in Abyssinia a little rain may fall at Suakin in July but usually the rainy season there is from October to February. At Massaua it is the same and as the tableland is approached the rains encroach on the summer months till at Ghinda both rainy seasons are experienced.

Red sea Coast Rainfall 1905 in Millimetres.

	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Massaua ...	6	13	3	149	—	—	—	—	11	—	3	53	[238]
Ginda ...	—	—	64	76	—	—	17	—	—	—	—	—	[157]
Suakin ...	17	3	0	0	0	0	0	0	7	0	122	0	149
Erkowit ...	—	—	—	—	—	—	—	—	—	—	227	132	[359]

In tables VII and VIII 24 stations are given for which 5 years observations are available, in order to show to what extent the rainfall of 1905 was above or below the average. This has been given in millimetres of rain in Table VII and as a percentage of the mean rainfall of the month in Table VIII. As in this latter case variations of a few millimetres would be shown as a large percentage variation in the months of the dry season, the figures relating to months having a mean rainfall of 50 millimetres or less are printed in italics.

TABLE VII

Difference of Rainfall of 1905 from the Mean in Millimetres

STATION (1)	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Zomba	—78	—	— 91	— 98	— 19	—12	— 6	— 1	— 7	—15	+106	+54	—
Tabora	+32	—93	+ 3	+ 54	— 23	— 4	0	0	— 7	— 5	+ 53	+36	+ 46
Zanzibar ...	—16	—105	— 28	+402	— 31	—14	+46	+24	+32	+41	—81	—21	+249
Mombasa ...	—18	—18	+ 82	+214	— 11	—10	—57	+11	—	—	—	—	—
Shimoni	—35	—18	+267	+440	+ 75	—54	+21	+89	—	—	—	—	—
Takaungu ...	—10	—14	+ 13	+225	— 90	—11	+68	—	—	—	—	—	—
Malindi	— 1	— 5	+ 56	+157	+ 7	+13	+ 3	—	—	—	—	—	—
Kismayu	— 1	+ 8	+ 50	— 21	— 5	—50	+68	—	—	—	—	—	—
Machakos ...	—20	—68	+198	— 37	+ 11	— 4	— 4	— 4	+ 3	+18	+39	+34	+166
Nairobi	— 9	—118	+183	+ 20	+ 54	—25	+ 4	+31	+14	+26	+ 4	+ 2	+186
Kikuyu	—24	—82	+263	+125	+100	—31	—26	+ 8	—	—	—	—	—
Eldama Ravine	+29	—50	+ 75	— 26	— 19	—66	—38	—	—	—	—	—	—
Mumias	+27	—36	— 1	— 76	+ 23	—105	—40	+90	—91	+44	+91	+118	+ 44
Kisumu	+49	—38	+110	— 52	— 63	—33	+19	+ 6	—10	—46	+18	+170	+130
Entebbe	—22	—68	+ 56	— 83	+ 37	+40	+72	—22	+24	+75	+22	+ 38	+169
Wadelai	— 5	—11	— 62	— 42	+ 13	—57	—23	+15	— 4	—15	—17	+ 61	—147
Gondokoro ...	— 3	— 2	— 52	— 36	— 22	—12	—28	+84	+13	+ 3	+ 8	+ 20	—37
Suakin	— 9	— 7	0	— 1	— 1	0	— 3	— 5	+ 7	—39	+31	—50	—77
Kodok	0	0	— 2	— 11	— 29	—25	—27	—135	+72	+79	+14	0	—64
Khartoum ...	0	0	0	0	+ 2	— 9	—16	+41	— 6	+40	0	0	+52
Addis Abbaba	— 4	—30	— 39	—	—	—	—	—	—	—12	+ 33	— 4	—
Roseires (1) ...	0	0	0	0	+ 14	+63	—26	—29	—14	+39	+13	0	+60
Addi Ugri ...	0	+ 9	— 4	— 4	+ 28	— 8	+67	+ 7	+19	+29	+15	— 5	+153
Kassala	0	0	0	— 2	— 5	+ 6	+24	+19	+58	— 17	— 1	0	+82

(1) Stations having at least 5 years observations except Roseires which has 3 only.

TABLE VIII

Difference of Rainfall of 1905 from the Mean as Percentage of the Mean Rainfall.

STATION[1]	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Zomba	— 27	—	— 42	— 97	*—100*	*—86*	*— 75*	*— 33*	*—78*	*— 35*	+ 81	+ 19	—
Tabora	+ 21	— 69	+ 2	+ 43	*—100*	*-100*	*0*	*0*	*-100*	*— 56*	+ 61	+ 25	+ 5
Zanzibar ...	— 21	— 98	- 18	+108	—11	—23	+ 87	+ *57*	+*73*	+ 39	— 53	— 13	+15
Mombasa ...	*— 78*	*— 82*	+122	+130	— 3	—11	— 69	+ 12	—	—	—	—	—
Shimoni	*—100*	*—100*	+272	+177	+19	—45	+ 18	+137	—	—	—	—	—
Takaungu ...	*—100*	*—100*	+ 24	+173	—25	—11	+ 67	—	—	—	—	—	—
Malindi	*— 14*	*—100*	+*233*	+103	+ 2	+11	+ 3	—	—	—	—	—	—
Kismayu ...	*—100*	*—800*	+*833*	*— 68*	+ 4	—63	+*148*	—	—	—	—	—	—
Machakos ...	*— 50*	—100	+146	— 19	+17	*—22*	*— 67*	*— 57*	+*60*	+ 35	+ 14	+ 29	+18
Nairobi	*— 20*	—100	+169	+ 11	+40	—44	+ *22*	+*155*	+*88*	+ *70*	+ 3	+ 2	+19
Kikuyu	*— 62*	—100	+165	+ 54	+53	—45	*—100*	+ *42*	—	—	—	—	—
Eldama Ravine	+ *71*	— 93	+ 94	— 23	—17	—73	— 52	—	-	—	—	—	—
Mumias	+ 34	— 38	— 1	— 33	+11	—54	— 24	+ 57	—52	+ 29	+ 59	—109	+ 2
Kisumu	+ 61	— 34	+ 89	— 34	—55	—44	+ *42*	+ *12*	—15	— 52	+ 12	+ 94	+11
Entebbe	— 28	— 79	+ 31	— 38	+22	+31	+100	— 33	+29	+ 83	+ 13	+ 26	+13
Wadelai	*— 18*	*— 58*	— 56	— 43	+10	—66	— 23	+ 13	— 4	— 9	— 15	+*179*	— 13
Gondokoro ...	*— 75*	*— 22*	— 95	— 44	—11	—21	— 21	+ 56	+ 9	+ 2	+ 15	+*167*	— 3
Kodok	*0*	*0*	*—100*	*— 92*	—53	—20	— 26	— 64	+65	+114	+*467*	0	— 9
Khartoum ...	*0*	*0*	*0*	*0*	+*50*	*—36*	*— 67*	+*121*	*—60*	+*400*	*0*	*0*	+49
Addis Abbaba	*— 44*	*— 81*	— 45	—	—	—	—	—	—	*— 92*	+*300*	*—100*	—
Roseires[1] ...	*0*	*0*	*0*	*0*	+28	+54	— 11	— 15	— 9	+*144*	+*118*	*0*	+ 8
Addi Ugri ...	*0*	+*150*	*— 31*	*— 18*	+*67*	—12	+ 43	+ 4	+*51*	+*290*	+*167*	*—100*	+28
Kassala	*0*	*0*	*0*	*—100*	*—71*	+*25*	+ 35	+ 18	+85	*—100*	*—100*	*0*	+28

(1) Stations having at least 5 years observations except Roseires which has 3 only.

Note. Numbers in italics refer to months in which the average rainfall is 50 mm. or less

Table IX. **TOTAL RAINY DAYS IN 1905**

STATION	May			June			July			August			Sept.			October			Nov.			Dec.		
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
Bahr el Ghazal																								
Tonj	—	—	—	[2	1	2]	5	4	2	6	4	0	5	3	4	3	2	5	4	3	1	...	...	...
Rumbek	—	—	—	[2	0	2]	6	2	7	7	0	8	3	0	8	3	0	3	7	0	3	...	...	...
Deim Zubeir ...	—	—	—	[1	1	5]	5	5	9	2	5	13	4	4	9	4	6	6	3	1	1	...	...	...
Chak Chak	—	—	—	—	—	—	8	2	5	...	...	...	...	...	...	..	..	..	...	...	...	...	...	...
Temboura	—	—	—	—	—	—	—	—	—	4	2	9	6	5	9	7	3	11	4	1	2	2	1	1
Meshra er Rek ...	—	—	—	—	—	—	4	3	4	3	4	2	[3	1	0]	3	3	2	...	...	...	...	...	...
Sept. { Meriddi ...	—	—	—	—	—	—	—	—	—	—	—	—	5	2	11	5	3	11	5	5	4	5	2	1
Sept. { M'volo ...	—	—	—	—	—	—	—	—	—	[3	2	4]	4	2	6	[4	2	3]	5	2	2	3	1	0
Kordofan																								
Taludi	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	4	1	2	...	...	...	...	...	...
Delling	—	—	—	0	0	3	1	2	9	3	4	7	2	3	8	2	2	4	...	...	...	...	...	...
El Adaiya	—	—	—	[1	0	3]	2	1	7	1	1	9	2	4	8	...	...	...	...	...	...	...	...	...
Gedid (Dar Gimme)	—	—	—	4	2	0	1	2	5	6	3	1	2	2	3	...	...	...	...	...	...	...	...	...
Khursi	—	—	—	[0	0	4]	2	0	5	1	0	4	0	0	2	1	0	1	...	...	...	...	...	...
Nahud	—	—	—	[2	1	2]	2	3	2	4	1	2	2	2	1	1	0	3	...	...	...	...	...	...
Sherkeila	—	—	—	—	—	—	3	4	3	2	6	4	0	1	2	5	1	1	...	...	...	...	...	...
Taiera	—	—	—	—	—	—	3	2	5	2	2	4	0	1	2	5	1	1	...	...	...	...	...	...
White Nile																								
Geteina	—	—	—	2	0	1	3	2	3	2	1	0	(1	0	0	...	...	...	See Table VI					
Kawa etc.	—	—	—	5	3	4	2	3	2	1	5	1	3	3	0	...	...	...	...	...	...	...	...	...
Goz abu Guma ...	—	—	—	4	1	3	3	2	6	7	3	1	2	1	3	...	...	...	...	...	...	...	...	...
Khartoum North ...	—	—	—	2	0	1	1	2	1	3	2	2	6	1	1	0	1	1	0	0	0	0	0	0
Omdurman	[3	0	0]	1	1	0	3	0	0	3	3	2	2	1	1	0	1	1	0	0	0	0	0	0
Blue Nile																								
Abu Naama etc ...	[1	1	2]	5	1	0	7	0	7	(1	4	5	5	2	2	...	...	...						
Singa	—	—	—	5	4	0	7	1	4	(10	3	1	5	1	2	0	2	1						
Managil	[1	0	0]	(	...	...	...	...	...	...	...	...	...	...	...	...	...	...						
Mesellemia ...	—	—	—	0	0	3	(	...	...	...	...	...	...	...	...	...	...	...	See Table VI					
Rufaa	—	—	—	3	1	1	(	...	...	...	...	...	...	...	...	...	...	...						
Kamlin	—	—	—	3	0	1	(	...	...	...	...	...	...	...	...	..	..	..						
Abu Deleig	—	—	—	9	1	0	(	...	...	...	...	...	...	...	...	...	...	...						
Sennar	[1	1	0]	6	3	1	(6	1	4	3	6	2	4	1	1	...	...	...						
Geili	[4	2	0]	2	0	1	2	1	0	3	1	2	2	3	1	...	...	...	...	...	...	...	...	...
Dinder	—	—	—	12	1	1	6	5	7	6	4	6	5	3	2	5	0	1	...	...	...	...	...	...
Dar Fung	[3	4	2]	7	5	5	1	1	1	2	5	4	5	3	3	...	...	...	...	...	...	...	...	...
Mafaza	—	—	—	4	2	1	5	2	7	5	1	2	5	0	0	3	0	1	2	0	0	...	...	...
Nile Below Khartoum																								
Shendi	[0	1	2]	1	0	2	0	0	3	1	0	3	1	0	7	0	0	0	1	0	0	0	0	0
Damer	[2	1	0]	0	0	0	2	0	0	3	0	1	2	1	3	1	0	0	0	0	0	0	0	0
Berber	[1	0	0]	0	0	0	1	0	0	0	0	0	5	2	2	0	0	0	0	0	0	0	0	0
Abu Hamad ...	[0	0	0]	1	0	0	0	0	0	0	0	0	3	1	0	0	0	0	0	0	0	0	0	0
Dongola	—	—	—	—	—	—	0	0	0	0	0	0	...	...	...	...	...	...	...	...	...	...	...	...
Red Sea																								
Tokar	—	—	—	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	1	0	1	0
Mohamed Ghul ...	—	—	—	0	0	0	0	0	0	0	0	0	0	1	4	0	0	0	1	3	5	0	1	0
Halayib	—	—	—	—	—	—	0	0	0	0	0	0	2	0	0	0	0	0	1	2	0	0	0	0
Karora	—	—	—	4	1	1	2	1	2	1	0	7	6	3	4	0	0	1	3	1	0	5	2	0
Akik & Karora ...	—	—	—	0	0	1	1	0	1	0	1	1	0	0	1	1	2	0	1	0	1	7	0	2
Port Sudan	—	—	—	—	—	—	—	—	—	0	0	0	0	0	1	1	0	0	...	...	...	...	...	...

A. — Total number of days on which rain was light
B. — „ „ „ „ „ „ „ moderate
C. — „ „ „ „ „ „ „ heavy

The rainfall may now be described month by month commencing in the southern part of the area.

At Zomba the winter rains were much below the average up to the end of the rainy reason:—

Rainfall in mm.

	Mean	1905	Deficiency in mm.	Percentage Deficiency
January	289	211	— 78	— 27
February	287	—	—	—
March	217	126	— 91	— 42
April	97	3	— 94	— 97

January. On the plateau of British East Africa the rainfall in January is normally about 40-50 mm. but this year it was deficient except at Eldama and Molo; round the Victoria lake though below the average at Entebbe, it was above it at Kisumu and Mumias, while in the north-east portion of the basin it was exceptionally heavy at Nandi (257 mm.), and Mohoroni (149 mm.) and Kericho (160 mm.) seem to be high. West of the lake rain was rather in excess at both Mbarara and Masaka though normal at Fort Portal. At Butiaba (on lake Albert) and at Wadelai a small deficiency appears but in this region the normal rainfall is so small that the deficiency cannot be said to be of any weight.

February. In February on the British East African plateau rain failed absolutely at five stations while 3 and 4 millimetres were recorded at the others; the normal rainfall probably approaches 80 mm. In the Victoria lake basin a similar deficiency occurs at every station until Mbarara, between the Victoria and Albert Edward lakes, is reached where there is an excess as compared with previous years as well as at Fort Portal and Butiaba. At Wadelai the normal rainfall is slight but less than half the usual amount was recorded.

March. In March the rainfall at Zomba and Tabora was deficient but no information is yet to hand which would show if the drought spread over a wide inland area since very different conditions prevailed over

the coast belt and the country generally to the northward. At the coast stations, and on the British East African plateau the precipitation was abundant, exceeding the normal by amounts ranging from 100 per cent. to over 200 per cent. On the Victoria lake the excess was less though still considerable, and to the west of the lake it affected all stations except Butiaba which was normal. To the north on the Bahr el-Jebel the almost complete failure of the rains continued, only 4 per cent. of the normal being recorded.

April. While in April the rainfall at Zomba failed almost completely, the defect on the coast of British East Africa was less pronounced, and on the plateau it was moderate at some stations while at others there was an excess. Stations to the north-east of the lake received a good rainfall while those on the lake shore were considerably below the average, as well as those to the west of it. On the Bahr el Jebel at most stations the rains begin in this month, and also on the lower reaches of the Sobat and on the White Nile but in 1905 in both these areas the April rains were abnormally weak.

May. In May the rainfall maintained its strength on the coast, but inland on the plateau both excess and defect were recorded, as well as in the lake basin both to the north and west. On the Bahr el Jebel excess occurred at Wadelai and Nimule but the rainfall was deficient in the lower reaches, and similar conditions were experienced at Nasser on the Sobat and on the White Nile. On the Blue Nile there was a slight excess, as well as in Eritrea, while on the Sudan plains the quantities registered were rather low.

June. In June the rainfall over the lake basin and in the region of the equator diminishes greatly and the rainbelt moves to the more northern countries. This year the reduction was very abrupt and the quantity which fell was considerably below the average on the coast and moderately so on the plateau and in the lake basin. On the Bahr el Jebel, the Sobat and the White Nile the deficiency continued to be considerable, though Wau in the Bahr el Ghazal and El Obeid in Kordofan were but little affected, while at stations on the plains of the Blue Nile, the Atbara, and the Khor el Gash as well as in Eritrea there was a fair excess.

July. In July the dry season has set in over the equatorial region and to the south of it; but rain was heavy to the north-east of lake Victoria at Nandi and Kericho, while the lake stations except Mumias recorded an excess; west of the lake there was a slight deficit, and on the Bahr el Jebel, the Sobat, and the White Nile a considerable one.

On the Abyssinian tableland rain was reported to be feeble especially in Shoa and this effect extended west as far as Roseires, but the Blue Nile plains beyond this had good rains as well as those of the Atbara and Gash, while in Eritrea there was a considerable excess.

August. In August there is little of importance to record on the equatorial region but at Butiaba and on the Bahr el Jebel there was a large excess which extended to the Bahr el Ghazal but which did not reach the Sobat and White Nile where rain was deficient. In Abyssinia the unfavourable conditions were unchanged and extended to Roseires, though in Eritrea and on the plains of the Atbara, Gash and the Blue Nile the rainfall was above the average.

Though no rain fell north of Merowe a heavy storm which passed over Khartoum on August 20 caused a thickly over-cast sky as far north as Aswan on August 21 where the occurrence caused much misgiving to the astronomers preparing to observe the total eclipse on August 30 lest similar conditions should prevail on that day.

September. In September the dry season is drawing to an end in the equatorial region, the Abyssinian rains are decreasing and on them largely depends the low stage level of the Nile in the following spring and early summer. In 1905 Abyssinian rainfall was poor, that of Eritrea above the average, as it had been throughout the summer, while the same favourable conditions were maintained over the Sudan plains and for the first time extended to the White Nile where the rains were considerably in excess at Kodok. Heavy rain at Merowe near Dongola in this month is probably unusual.

On the Sobat rainfall was above the average, as it was also at all the northern stations in the Bahr el Jebel, and at Wau in the Bahr-el-Ghazal. In the neighbourhood of Ghaba Shambe, where 232 millimetres were recorded, the rainfall was exceptionally heavy and its effect on the wide expanse of marsh, which occurs at this part of the Bahr el Jebel, was to raise the water level and add a considerable supply to the main river for a short time. This point is considered further on p.31

October. In October the Sudan rains improved generally but as at this season the normal rainfall is light the effect was slight.

In November rain has normally ceased in the Sudan and in Abyssinia except on the eastern coast of the plateau. At Addis Abbaba heavy rain fell, and at the end of the month it was reported as being unusually heavy on the Abyssinian plateau near the sources of the

Sobat. On the Bahr el Jebel rain was about normal, but it was considerably above the average on the north shore of the Victoria lake and moderately so on the plateau of British East Africa, while at Zomba it was very heavy.

December. In December the conditions were generally the same, so that after a very poor summer rainfall at most places north of the Equator the autumn rains showed a marked improvement, but so far as the latest information goes, in British Central Africa at least rainfall in January and February 1906 are much below the average.

The lake and river levels in 1905.

At the end of 1904 [1] it was pointed out that weak autumn rains following a poor Nile flood would inevitably cause very low levels at low stage in 1905, and this was fully borne out, since the Nile at Wadi Halfa was much below the average and the late arrival of the rains increased the deficiency.

DIFFERENCE IN CENTIMETRES BETWEEN 5-DAY MEANS OF GAUGE READINGS AT WADI HALFA 1905 AND THE MEAN VALUES OF 1890-1904

	1-5	6-10	11-15	16-20	21-25	26-31	Mean
May	—37	—40	— 41	— 44	— 44	— 45	— 42
June	—46	—54	— 60	— 66	— 80	— 86	— 65
July	—91	—88	—104	—135	—158	—168	—124

The level of lake Victoria was fairly high in 1904 though it fell in the latter part of the year; in 1905 there was a very low maximum in May followed by a steady fall which lasted until the end of the year. The mean level of the year (Kisumu, Port Florence gauge) and the change of level in the year as compared with those of previous years is given in the following table :

(1) The Rains of the Nile Basin in 1904. Cairo, 1905 p. 25.

	Mean[1]	Maximum[1]	Minimum[1]	Mean Level[1] January	Change[2]
	m.	m.	m.	m.	mm.
1896	0.928	1.14	0.67	1.10	
1897	—[3]	—[3]	—[3]	0.86	—240
1898	—[3]	—[3]	—[3]	—	—
1899	0.733	1.09	0.30	0.95	+ 90[4]
1900	0.391	0.67	—0.02	0.45	—500
1901	0.508	1.05	0.16	0.32	—130
1902	0.172	0.44	—0.02	0.18	—140
1903	0.742	1.05	0.24	0.37	+190
1904	0.917	1.38	0.66	0.85	+480
1905	0.696	1.00	0.59	0.73	—120

The Albert lake fell rapidly in February and only rose slightly in September and October until the level at the end of the year was 0.42 metre less than at its commencement, so that if it is assumed that the same fall took place on the Wadelai gauge about 90 cubic metres per second less were leaving the lake in December 1905 than in January.

The actual change on the Wadelai gauge is not known as connection between the gauge-well and the river was found in March 1905 to be sanded up, and on clearing it, the water level in the gauge well fell 0.54 metre; the level then fell until the latter part of August, but rose 0.2 metre in September and October. The almost complete failure of the rains on the Bahr el Jebel is clearly shown by the gauges, (Plate IV) for, except a few sudden rises in May, there was no decided increase of the water-level until the middle of August, while a fall towards the end of September was followed by a considerable rise in the middle of November, due to the unusually heavy autumn rains. A similar late and heavy rainfall in the Bahr el Ghazal is shewn by the gauge on the Jur river at Wau (Plate VI).

A river gauge was erected at Bor early in the year and readings commenced from May 12. This gauge is most instructive for it shows only a slight rise of 0.15 metre in June, a hardly perceptible one of 0.05 metre in September and another of about an equal amount in November; the rises shown by the Gondokoro and Mongalla gauges

(1) These values differ by - 65 cm. from the values communicated to Irrigation offices in Egypt since for these latter the lake level at Kisumu Dec. 31st. 1903 was taken to be 1.50 m.

(2) i. e. difference between mean level in January of each year.

(3) Incomplete.

(4) from Jan. 1897 to Jan. 1899.

175 and 134 kilometres up-stream respectively have disappeared since the water has spread out in the lagoons and channels of the valley, as the measured discharges shown. Further down the river at Ghaba Shambe the change of level is greater again but this is due more to rainfalling on and draining into the wide expanse of marsh near this point than to the passage of a flood-wave down-stream.

The maximum and mean level of the water at Ghaba Shambe were 1.80 metres and 1.48 metres as compared with 1.95 and 1.59 of the previous year.

A little north of Kenisa after the eastern branch of the Bahr el Jebel (known as the Awai) rejoins the main-stream the marshes of the valley reach their greatest development. They have not as yet been surveyed but since the higher dry ground is not far from the Bahr el Jebel on the west [1], and Captain Liddell's [2] route limits their extension towards the east, it may be said as a fair approximation that they cover an area measuring some 100 kilometres from north to south and 40 kilometres from east to west. Into this drain normally the Myding, a branch of the Awai, which is described as blocked by vegetation at a short distance from where it enters these marshes, and also one large and numerous smaller branches of the Bahr el Jebel. Besides these a considerable amount of water must be brought into these marshes by the khors and drainage lines from the east and south-east in the rainy season besides what actually falls on this area as rain. This marsh-basin supplies the Bahr el Zaraf which is not simply a branch of the Bahr el Jebel, as has been frequently asserted, but is a perennial stream fed by these marshes and by the rainfall draining into it lower down its course. Sir Samuel Baker [3] and Commandant Henri [4], both of whom made their way into the Bahr el Jebel from the upper reaches of the Bahr el Zaraf in years when the former channel was blocked by sadd, were only able to do so with the greatest difficulty. Sir Samuel Baker had to cut a channel for a considerable length for his boats and artificially raise the water level by means of a dam, while Commandant Henri speaks of having to drag his boats for long distances sometimes through channels a metre or so wide and at others traversing sheets of water only 20 centimetres deep.

(1) Sir W. Garstin - A Report on the Basin of the Upper Nile, Cairo 1904 Maps.
(2) Geog. Jour. Dec. 1904
(3) Ismailia, London 1874, Chap VI.
(4) Bul. Soc. Etudes Coloniales Brussels 1902.

Though the sadd which has so often blocked the channel of the Bahr el Jebel has most frequently occurred in the last 100 kilometres of its courses at a short distance down-stream of Ghaba Shambe there is a point where blocks occurred in 1878-9 and again more recently. It was easy to connect this with the large expanse of marsh at this part of the river but the rainfall of 1905 directs attention to the important part that rainfall on this area plays in disturbing the stability of river and valley at this point. Discharges measured by the Sudan Irrigation Service on September 30, 1905 showed that a branch coming from these marshes was bringing into the Bahr el Jebel 200 cubic metres per second more than a large branch which left it several kilometres higher up was taking out, while the Ghaba Shambe gauge readings clearly show the rise of level due to the September rains which were unusually heavy. Though records of the water level of the Bahr el Jebel and the rainfall in this part of the country are scarce, a few have been preserved which show how greatly this portion of the valley is affected by heavy rainfall. In 1859 rains on the Bahr el Jebel failed until the end of June but afterwards they were very heavy(1). Kaufmann(2) recorded a total rise of 1.9 metre at the Austrian Mission at Kenisa. In 1861 the rains were again late but very heavy at the end of the summer ; Poncet(3) states that it rained continuously from August 20 until September 20, and the river rose until September 22, only commencing to fall on October 10. The Mission station is said to have been an island 50 paces by 8 in the midst of flooded marshes. In 1878, a year of heavy rainfall, the Bahr el Jebel was blocked 8 kilometres below Ghaba Shambe(4) but Emin Pasha was able to pass round it without difficulty showing that water was high in the marshes and back channels. Thus the wide area of marsh which may receive within a short time very large quantities of rain must seriously affect the conditions of this length of the river, and greatly increase the difficulties of maintaining it in a stable condition.

The rainfall on this part of the Bahr el Jebel is therefore of especial interest as affecting it in an unusual degree, and it will have

(1) Morlang Pet. Mitt. Erganzungshand X and Pruyssenaere Pet. Mitt. Erganzungsheft 50 p. 8.

(2) Das Gebiet des weissen Flusses. Brixen 1861 and Pet. Mitt. 1861 p. 368.

(3) Le Fleuve blanc p. 47.

(4) Pet. Mitt. Erganzungsheft 11. 1863 pp. 139-140.

(4) Pet. Mitt. 1881 p. 421.

to be taken into consideration in deciding upon the most advantageous means of increasing the volume of water which reaches the White Nile.

The following table gives the daily rainfall for the month of September 1905 at stations in this part of the country

Rainfall (in millimetres) September 1905

Date	Gondokoro	Mongalla	Bor	Ghaba Shambe	Wau	Doleib Hilla	Nasser
1	19	50	16	—	40	2	5
2	—	—	17	36	—	—	—
3	—	—	—	—	—	—	—
4	—	—	20	—	10	6	—
5	—	—	—	4	2	—	—
6	—	—	—	1	—	4	8
7	—	—	—	—	—	—	—
8	3	—	—	—	34	—	—
9	6	3	—	—	—	19	—
10	—	—	—	—	28	47	23
11	29	32	—	22	5	1	—
12	6	1	16	—	—	—	—
13	—	—	—	2	—	—	—
14	6	38	—	—	14	—	—
15	9	—	—	—	2	—	—
16	—	—	18	87	—	—	—
17	—	—	—	—	—	—	—
18	—	—	—	—	—	—	—
19	—	—	—	—	—	1	26
20	—	—	—	—	4	73	—
21	—	—	—	—	—	—	—
22	41	30	16	—	—	—	—
23	3	—	18	2	—	—	40
24	—	—	—	17	—	—	—
25	—	—	—	—	—	—	—
26	18	3	20	—	1	—	—
27	2	—	—	—	—	—	—
28	—	—	—	—	4	—	—
29	12	17	—	—	—	—	12
30	—	—	8	59	—	—	5
TOTAL	154	174	149	230	144	153	119

On the Sobat a new gauge was erected at Gambela a little downstream of the junction of the Baro and the Birbir rivers, at the point where the Baro leaves the hills, and readings were commenced on May 5. The river is a true mountain stream at this point rising and falling rapidly as its different tributaries come down in flood. A comparison of this gauge with that of Nasser is most instructive; the first rises at Gambela are quickly and sharply reproduced on the downstream gauge 266 kilometres away, but later as the Baro rises, it ponds back the waters of the rivers coming from the plains to the south, reducing their water-slope and causing their waters to flood the low plains through which the Pibor and other rivers flow, so that the lower gauge ceases to reproduce them and after the middle of July shows a steady undisturbed rise. A break in the rains at the end of September, which caused a fall of over 2 metres at Gambela, was unfelt at Nasser where the level was presumably maintained by water from the flooded Pibor plains, into which the Akobo, the Gelo and other rivers from the Abyssinian plateau pour their waters. In the latter part of November a heavy burst of rain on the plateau checked the fall and until the end of November (see plate V) the river at Gambela maintained a nearly constant level.

The Sobat was effected by the deficient rainfall of the summer months as is shown in the following table : —

Mean level of the River Sobat at Doleib Hilla in metres.

Year	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1903	0.48	1.46	1.99	2.54	3.03	3.39	3.49	3.52
1904	1.09	1.76	2.29	2.70	3.02	3.18	3.22	2.94
1905	0.53	1.05	1.74	2.22	2.61	2.82	2.92	[2.89]

The first signs of the rise appeared at Nasser on May 1 and at Doleib Hilla on May 11, while in 1904 the corresponding dates were March 5 and March 10.

On the White Nile the water-level is determined by the Sobat at Taufikia and at Dueim from November to June, while the Blue Nile flood controls it from July to October. The levels this year were consequently below the average, since these rivers were low.

On the Blue Nile the water-level was recorded at Roseires, Sennar, Wad Medani and Khartoum, but at Wad Medani errors were made in reading the gauge so that for the 1905 flood season it is only useful for showing the date of the various rises and falls at this point of the river, and cannot be taken as a record of the water-level since the range was 5.80 metres against 8.82 metres in 1903; no difference of such magnitude is shown by the other gauges. The river rose first at Roseires on May 1, a date not very different from that of 1904 though in that year there was also a small early rise in the latter part of March, but as the summer went on the rise was less rapid than usual in consequence of the weakness of the rains throughout Abyssinia. The maximum gauge reading was recorded at Khartoum on September 7, the average date, but the period during which it stood near the highest level was about 5 weeks only against 7 in 1904.

The difference in the volume of the two floods may be shown by comparing the volumes passing Aswan between July 21 and October 31 in the three years 1903, 1904, 1905 :—

Mean volume passing Aswan in millions of cubic metres per day

Month	Period	1903	1904	1905
July	21 - 25	142.6	168.5	71.3
	26 - 31	180.6	254.9	92.4
August	1 - 5	215.1	337.0	160.4
	6 - 10	274.8	482.1	214.3
	11 - 15	364.2	630.7	229.0
	16 - 20	532.7	591.0	313.6
	21 - 25	717.1	566.4	527.5
	26 - 31	784.1	546.9	578.9
September	1 - 5	727.5	549.5	582.3
	6 - 10	764.6	580.6	591.0
	11 - 15	786.2	606.5	625.5
	16 - 20	755.1	580.6	622.1
	21 - 25	715.4	570.2	575.4
	26 - 30	717.1	559.9	577.2
October	1 - 5	691.2	511.9	559.9
	6 - 10	611.7	469.2	502.8
	11 - 15	567.6	4066	426.4
	16 - 20	531.4	348.6	340.8
	21 - 25	474.3	297.2	281.7
	26 - 31	418.6	262.7	235.0

The satisfactory development of the rains in Eritrea, where they were above the average throughout the summer, produced a more favourable flood in the Mareb, and its lower reach the Khor el Gash, than has been experienced for several years. This hardly seems to have reached the basin of the Takazze and the Setit sufficiently to affect the river supply until late in the season for though the highest readings at Khashm el Girba were above those of 1904 the Berber gauge reached 3.2 metres on July 20 against July 5 in 1904, and fell to this level on November 28 against November 22 in 1904; still the gauge at Khashm el Girba was higher at the end of October 1905 than in 1904 showing that the rains in Abyssinia had somewhat improved. The November rainfall at Addis Abbaba was 44 mm. or 37 mm. above the average and heavy rainfall was reported from the upper reaches of the Baro in the latter half of this month, while the Roseires gauge readings substantiate this late improvement in the rains by a rise in the middle of October and another in the second week of November. This will probably improve the low stage conditions of the river in the early summer of 1906, which promised to be extremely low in consequence of the feeble flood and the early cessation of the rains on the Abyssinian plateau. This improvement is shown by the readings of the Khartoum gauge.

Difference From 6-Year Mean 1900-1905 in centimetres.

5-day period	October	November	December	January 1906.
1 - 5	—21	—32	+ 5	+14
6 - 10	—35	—21	+ 9	+19
11 - 15	—36	—11	+13	+26
16 - 20	—44	— 2	+ 8	+33
21 - 25	—47	+ 2	+ 4	+31
26 - 31	—37	0	+ 6	+35
Mean	—37	—11	+ 8	+26

Meteorological Conditions of the Summer months.

Looking back over the floods of recent years we see that since 1896 all the floods except that of 1898 have been below the average, and it has been maintained that such a series is wholly unprecedented. Hence, it is argued, conditions must have changed in the regions of the Upper Nile and a permanently reduced flood supply is to be anticipated as the result of this assumed change of conditions, which is assumed to be permanent. But for this despondent view no real ground exists. In the first place a similar dry period has affected India, Australia and South Africa, which also border on the Indian Ocean, and though the same degree of deficiency has not been recorded in each of these areas in any one year, they have all suffered from a general feebleness of precipitation.

The reduced rainfall on the Abyssinian tableland during these past 7 years is not an isolated case, but is due to meteorological conditions which have similarly affected a very wide area.

Beyond 1719 the record of the Nile flood at Roda is much broken, but from this date to 1800 and again from 1825 to 1905 we have reliable records for 163 years. It will be seen from Plate VIII that several groups of years occur in which low floods greatly predominated. The most pronounced is that from 1781 to 1799 in which all floods except those of 1787 and 1798 were below the average, those of 1782, 1783, and 1784 being particularly low. After the high flood of 1829 all floods except that of 1834 were below the average until 1840, while 1864-8 and 1880-1886 were periods of minor defect. Thus periods in which low floods predominante have lasted in the past for even longer than in the present case without a permanent reduction resulting. It must be admitted however that very little is known as yet of the factors which exercise most influence on precipitation in the various parts of the lands which surround the Indian ocean. So far as the basin of the Nile is concerned the experience of 1905 emphasises the necessity for extreme caution in drawing deductions from scanty materials, for, as we have seen, excessive precipitation in the coast and in British East Africa, and in Eritrea was associated with extreme deficiency on the Bahr el Jebel and on the central and southern parts of the Abyssinian plateau. I have pointed out that there is very frequently a relation between the rainfall of Abyssinia and the atmospheric pressure over north-eastern Africa such that about 6 cases out of 7 in 36 years showed

excess of pressure in years of scanty flood while in years of floods above the average, the pressure was in defect.

In 1905 this held good as the pressure was in excess at almost all stations throughout Egypt and the Sudan though at Wadi Halfa, Berber, and Suakin some months were slightly below the average of the last 4 years which have however all been above the normal in the summer months as judged by the records of Beirut, Alexandria and Cairo.

Differences of the Atmospheric Pressure from the Normal—1905

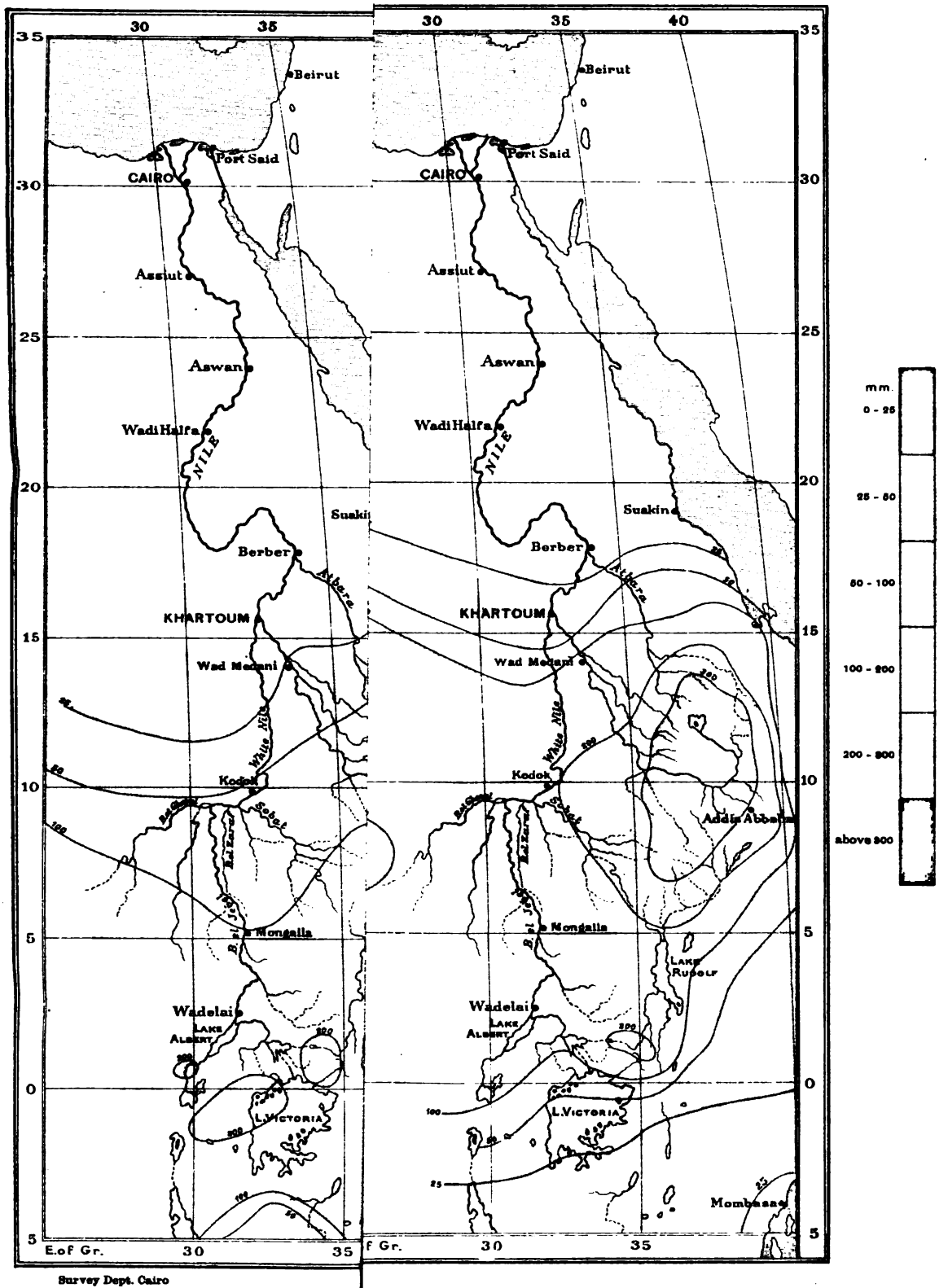
PLACE	Years of observations	May mm.	June mm.	July mm.	Aug. mm.	Sept mm.	Oct. mm.
Beirut . .	31	— 0.5	+ 0.2	— 0.3	— 0.7	— 1.6	— 1.0
Port-Said...	5	+ 0.4	+ 0.8	+ 0.6	+ 0.1	+ 0.5	+ 0.1
Alexandria	34	+ 0.4	+ 0.5	+ 0.4	— 0.2	— 2.8	— 0.9
Cairo ...	'22	+ 0.6	+ 1.1	+ 1.5	+ 0.9	— 0.2	+ 0.7
Assiut ...	5	+ 1.6	+ 2.7	+ 2.9	+ 2.0	+ 1.3	+ 1.4
Aswan ...	5	+ 1.0	+ 1.3	+ 1.1	+ 1.1	+ 0.9	+ 1.2
Wadi Halfa	4	— 0.1	— 0.3	+ 0.1	0.0	— 0.7	0.0
Berber ...	4	+ 0.7	+ 0.2	0.0	— 0.6	0.0	+ 0.2
Suakin ...	4	+ 0.2	+ 0.1	— 1.1	0.0	— 0.2	+ 0.5
Khartoum	5	+ 2.3	+ 3.0	+ 1.5	+ 1.5	+ 0.3	+ 0.8
Wad Medani	4	+ 1.0	+ 0.4	+ 0.6	+ 0.8	+ 0.6	+ 0.7
Ducim ...	4	+ 0.9	+ 0.6	+ 0.5	+ 0.7	+ 0.2	+ 0.5
Aden ...	25	+ 0.6	+ 1.3	+ 0.8	+ 0.1	— 0.2	— 0.1
Mauritius	—	+ 0.7	— 0.2	— 0.6	— 0.1	— 1.2	— 0.4
Zomba ...	7	+ 0.2	— 1.8	+ 0.6	— 0.3	— 1.6	— 0.3

UNIV. OF MICH.

MAY

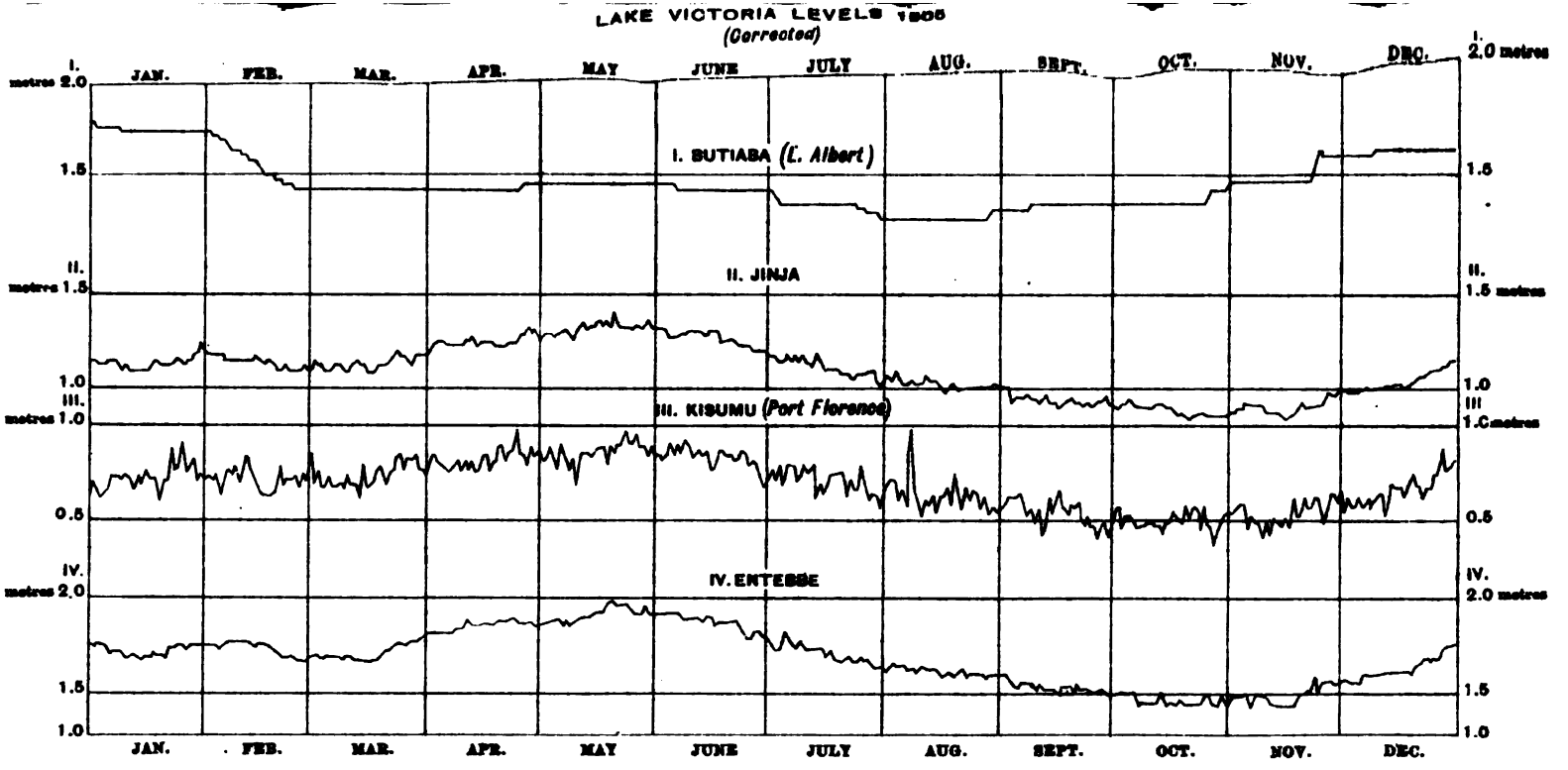
AUGUST

PLATE IIb.

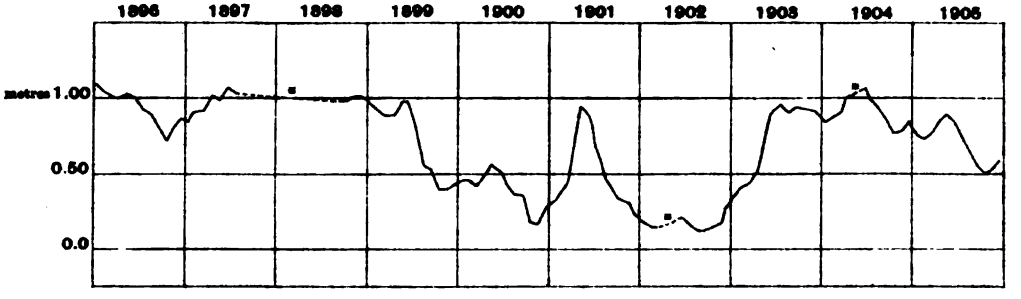


Survey Dept. Cairo

UNIV. OF MICH.



LEVEL OF LAKE VICTORIA
KISUMU GAUGE



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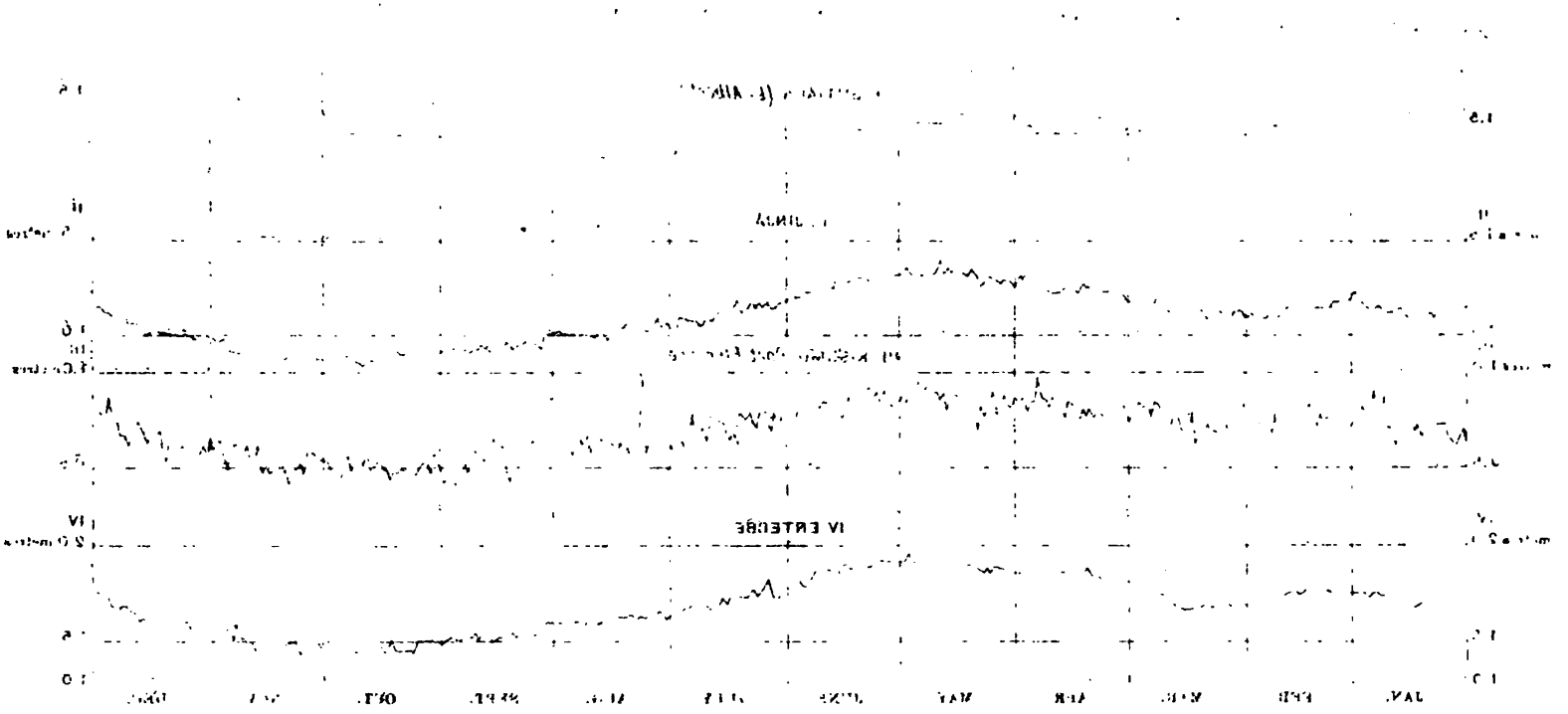
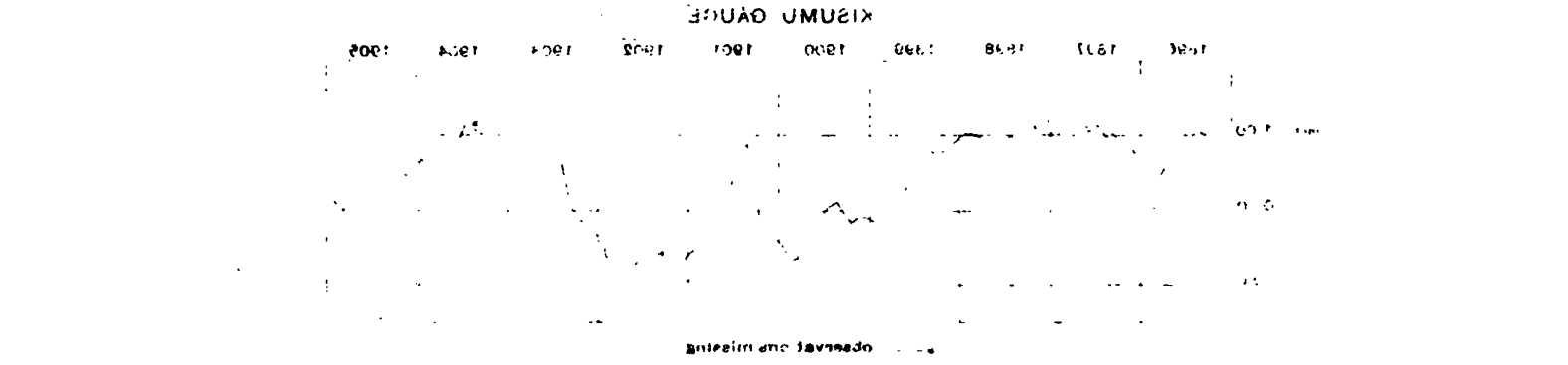
SURVEY DEPT.





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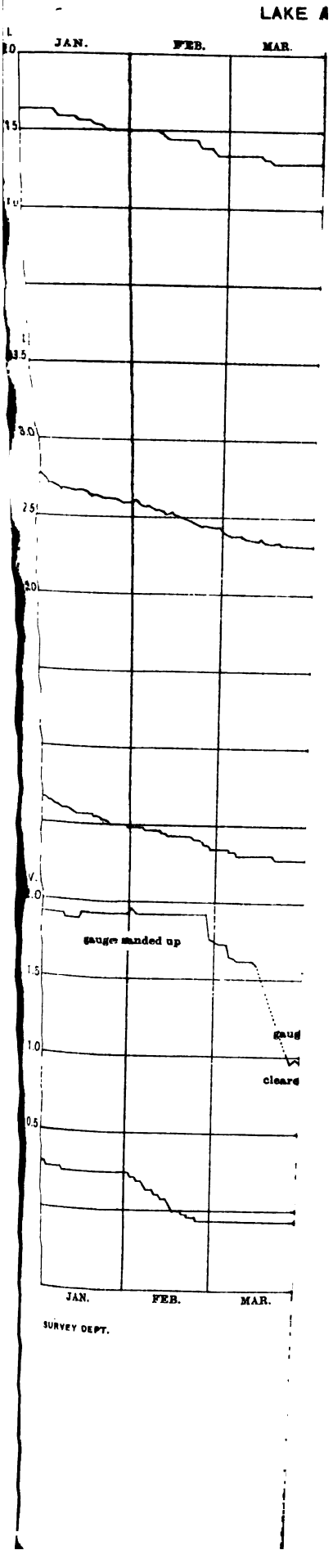
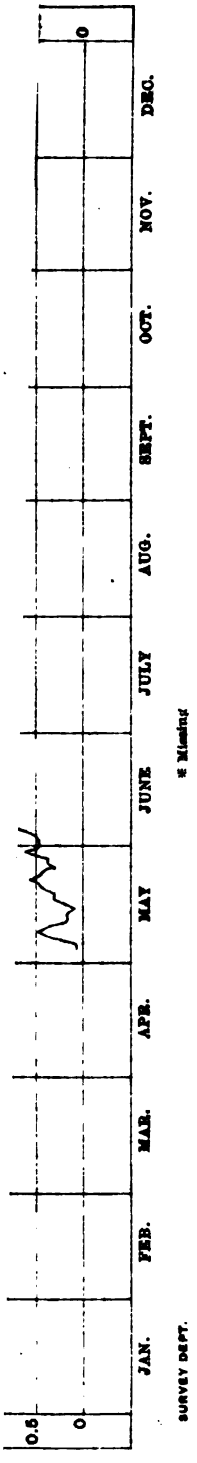

LAKE A
JAN.
FEB.
MAR.
3.5
3.0
2.5
2.0
1.5
1.0
0.5
gauge manded up
gaug
clears
JAN.
FEB.
MAR.
SURVEY DEPT.


0
DEC.
NOV.
OCT.
SEPT.
AUG.
JULY
JUNE
MAY
APR.
MAR.
FEB.
JAN.
0.5
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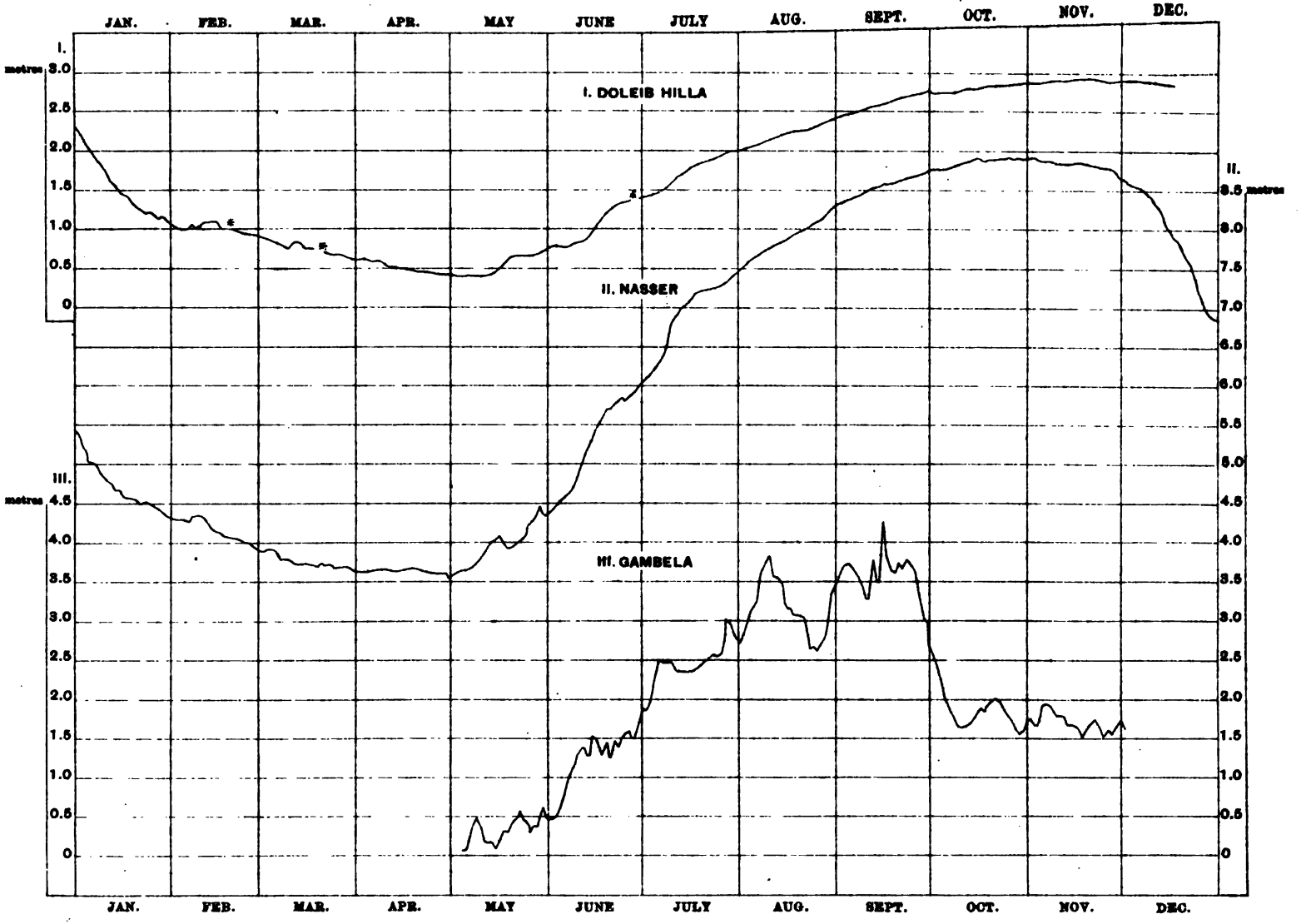
* Missing
SURVEY DEPT.

Approved For Release

PLATE V.

RIVER SOBAT GAUGE READINGS 1905 IN METRES



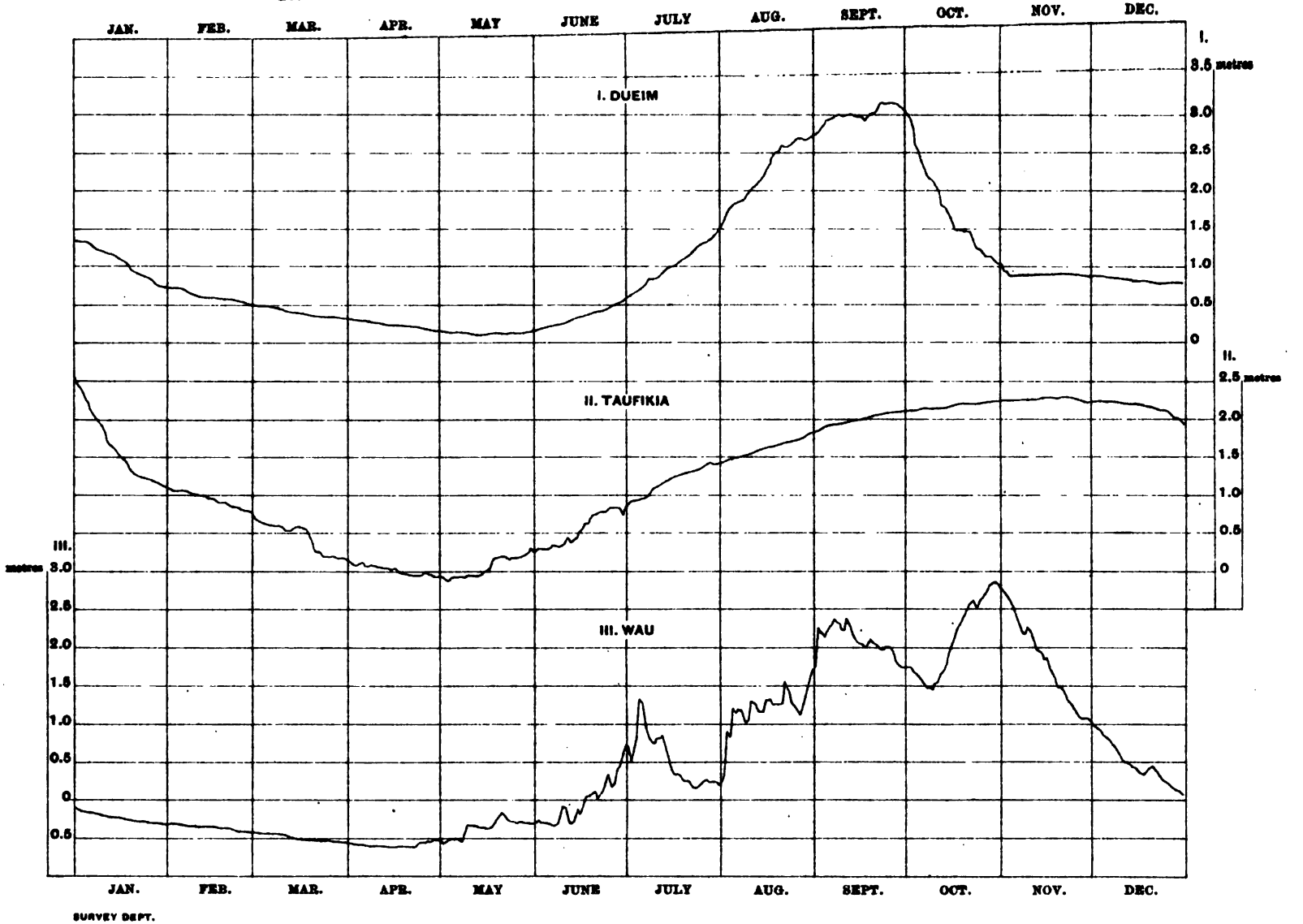
SURVEY DEPT.

* Missing

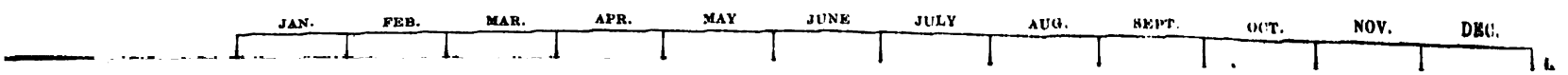
PLATE V
RIVER SUNGEI PAHANG HEADING FOR MALACCA STRAITS
DEC
NOV
OCT
SEPT
AUG
JULY
JUNE
MAY
APR
MAR
FEB
JAN
DOLED HILLA
II NASSER
III GAMBIA

PLATE VI.

BAHR EL GHAZAL AND WHITE NILE GAUGE READINGS 1905 IN METRES



SURVEY DEPT.

UAW III
AIM-CAT II
MIDJO I

BLUE NILE GAUGE READINGS 1905 IN METRES